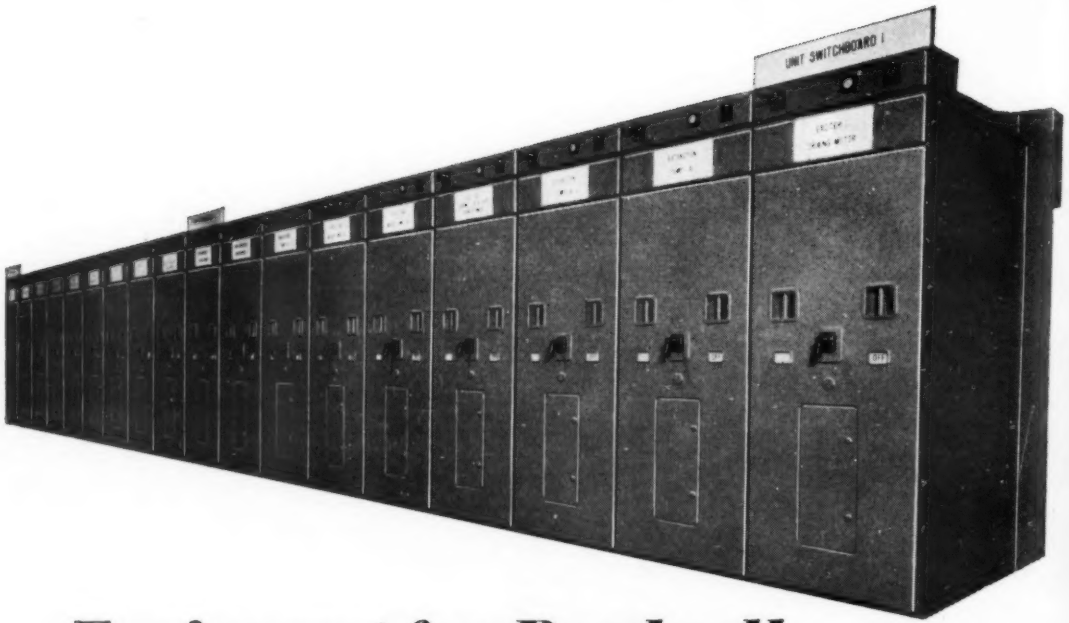
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

SEPTEMBER 1959

G.E.C.

power generation



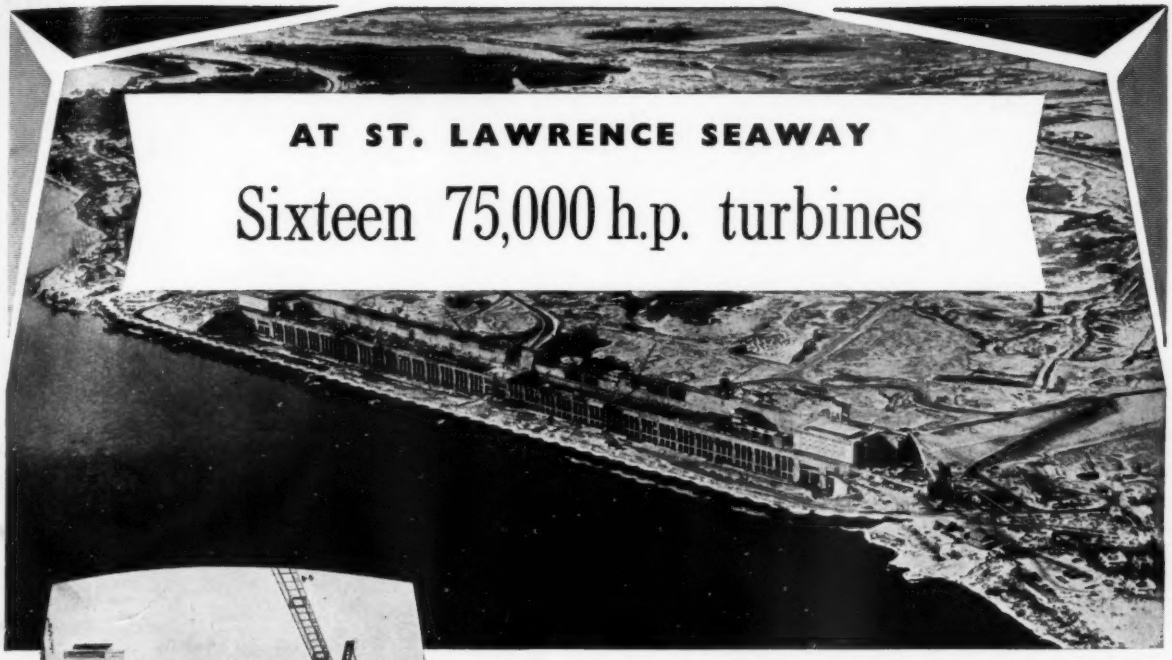
Equipment for Bradwell

All the switchgear comprising the main 132-kV air-blast circuit-breakers, 6·6-kV, 3·3-kV, and 415-volt air-break equipment for auxiliary supplies, together with its associated control apparatus for Bradwell Nuclear Power Station is being supplied by Reyrolle who are responsible also for the reactor control-rod heads, the fission-products detection equipment, and the machining of the graphite blocks.

Reyrolle specialists in switchgear and control-apparatus

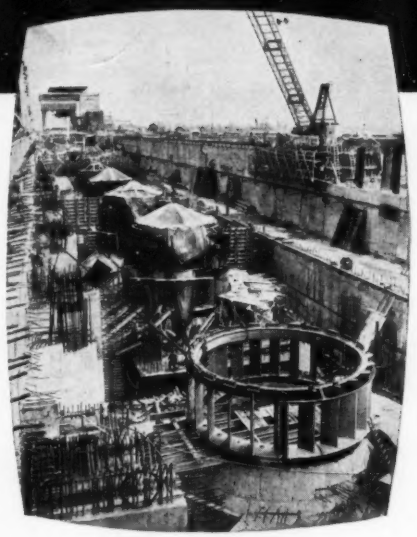
MEMBER OF THE NUCLEAR POWER PLANT CO. LTD. NPC

A. Reyrolle & Company Limited · Hebburn · County Durham · England



AT ST. LAWRENCE SEAWAY

Sixteen 75,000 h.p. turbines



Part of the vast power house, during construction, showing some of the 'ENGLISH ELECTRIC' *turbines in position.*

will generate Canada's share of power from this international project

For the international St. Lawrence Seaway Power Project, sixteen 'ENGLISH ELECTRIC' 75,000 h.p., 81 ft. head water turbines are being supplied on the Canadian side and will provide the whole of Canada's share of the power from this project. Nine of the turbines have already been commissioned.

The turbines of 'ENGLISH ELECTRIC' design are manufactured by English Electric Canada, a Division of John Inglis Co. Limited.

'ENGLISH ELECTRIC'

water turbines

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

ENGLISH ELECTRIC CANADA (A DIVISION OF JOHN INGLIS CO. LTD.) ST. CATHARINES, ONTARIO

Offices and representatives throughout the world

HE.36

VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE, LINZ-DONAU, AUSTRIA

VÖEST

Hydraulic Turbines, Spherical and Butterfly Valves

Licensed by Baldwin-Lima-Hamilton Corp.
Philadelphia, U.S.A.

HYDRO-ELECTRIC POWER
building a
new future
for the
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SOUTHAMPTON
CABLES

64'000 HP Pelton Turbine Göschenen

TRADITIONAL SWISS ENGINEERING SKILL AND QUALITY

A century of experience in design and construction of waterpower-equipment and constant research in two hydraulic laboratories, one of them especially equipped for cavitation tests, assure the reliablity and efficiency for which Bell turbines are renowned

KRIENS Bell

Bell builds:
Water Turbines, Spherical straight flow valves, Butterfly valves, Penstocks and supply pipings, Pressure tunnel liners, Partially or fully automatic and remote controlled plants, Power house cranes, Towers for transmission lines, Water control equipment

Some projects with Bell Equipment:
Francis Turbines - Guyabo (El Salvador) head 56 m, 24'800 HP - Bärenburg (Switzerland) head 340 m, 85'000 HP (Supply together with Charmilles)
Pelton Turbines - Göschenen (Switzerland) head 698 m, 64'000 HP - Sedrun (Switzerland) head 588 m, 70'000 HP
Kaplan Turbines - Wildegg Brugg (Switzerland) head 15,3 m 34'000 HP - Petäjäskoski (Finnland) head 19 m, 67'600 HP

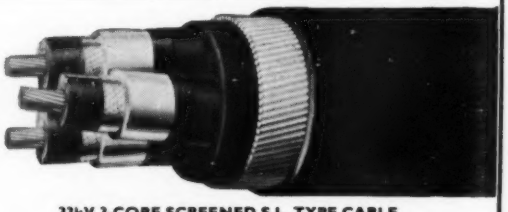
Bell Engineering Works Ltd.
Kriens/Lucerne (Switzerland)

POWER

Created by Bernini in the 17th century, this lithe sculpture of David stands in the Galleria della Villa Borghese, Rome, a gleaming tribute in bronze to the sculptor's conception of power.

In our modern world, power — electrical power—is the great motivator of our industries, the light and warmth of our homes. And wherever electricity comes from, wherever it goes, Henley cables carry it surely and safely. No manufacturer has more experience in the design and manufacture of supertension cables up to 132 kV.

David, *by Bernini.*
In the Galleria della Villa Borghese, Rome.



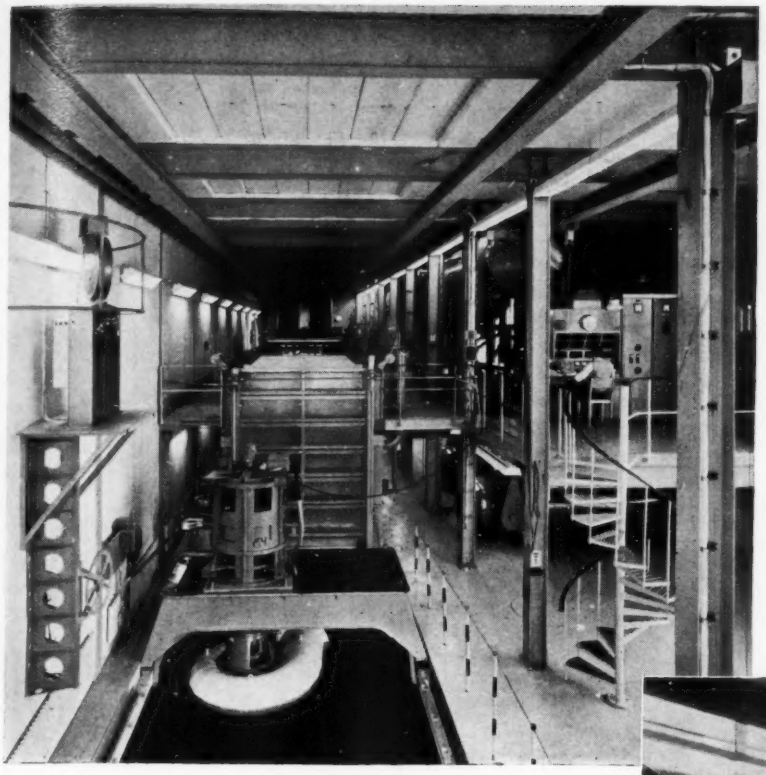
33kV 3-CORE SCREENED S.L. TYPE CABLE

POWER CABLES by HENLEY

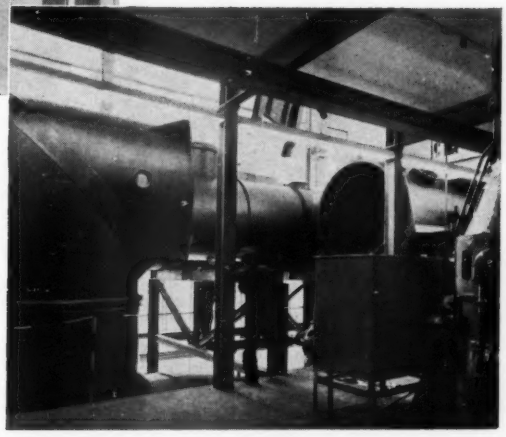
An A.E.I. Company

BY APPOINTMENT TO HER MAJESTY THE QUEEN ELECTRIC CABLE MANUFACTURERS

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD · 51-53 HATTON GARDEN · LONDON E.C.1 · Tel: CHAncery 6822



The main plant in the new laboratory is the large flume through which water flows to the turbine model.



Erection of the cavitation tunnel. The tunnel is intended for tests with large turbine models of Kaplan or propeller type.

KMW's new Turbine Laboratory at Kristinehamn -one of the best equipped in the world

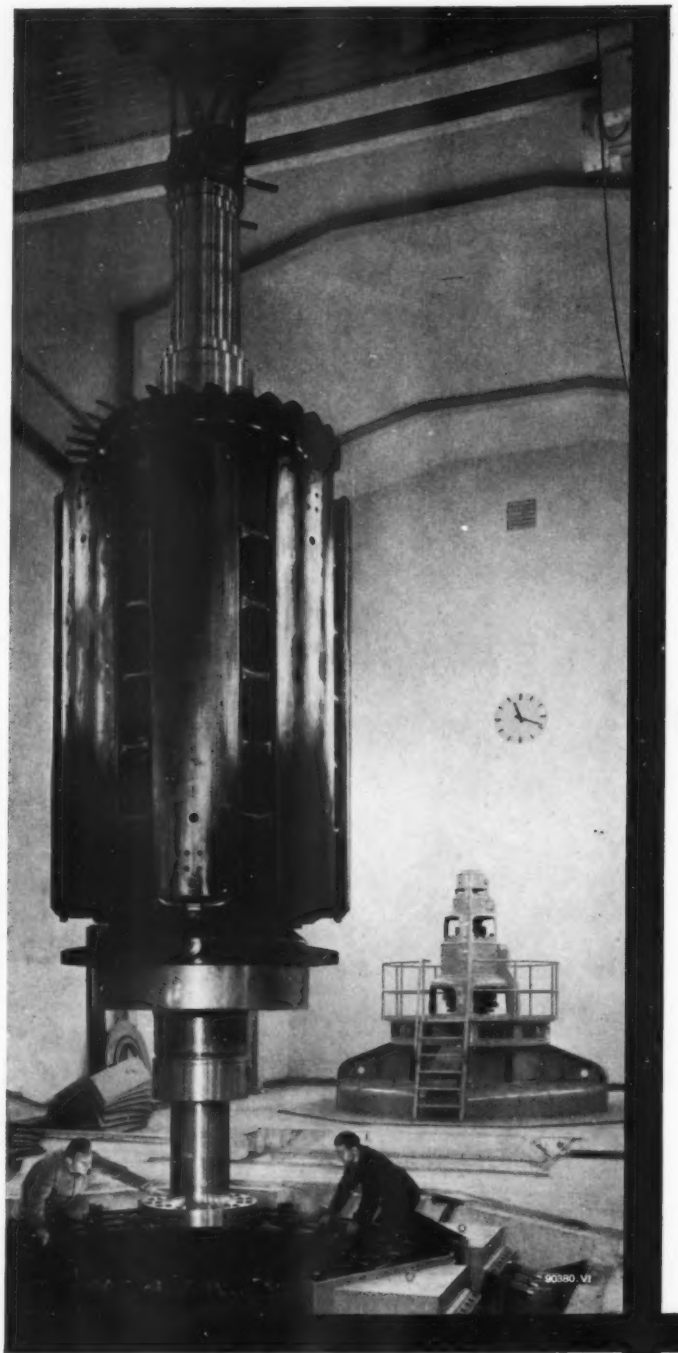
The water power of the world is being exploited at an ever increasing rate. Turbines are being further developed and new types are appearing. The size of the average unit is increasing and greater demands are placed on performance. This calls for constant research and development work.

In this connection KMW as turbine manufacturers are well to the fore and for a long time past have maintained their position among the world's leading concerns in this field by extensive technical development work, above all in respect of the hydraulic design of the turbines. In order to intensify this activity still more, a completely new hydraulic laboratory has recently been put into service. The stationary equipment consists at present of three main units: an open flume circuit, where large model turbines can be tested under a head of 4 m, and two separate cavitation tunnels. One of the tunnels is intended for tests with models of high pressure turbines under heads up to 100 m, while the other, which like the flume has been proportioned for large scale models, is adapted for tests with low heads and large volumes of water. Controls and instrument readings are centralized. The measuring equipment is to a large extent electronic and permits great accuracy and rapid tests.

AB KARLSTADS MEKANISKA WERKSTAD
KARLSTAD - SWEDEN

Representatives in Canada: A. Johnson & Co. (Canada) Ltd.,
607 Shell Tower Building, Montreal 2.

KMW



Brown Boveri leaders in the design of high-speed salient-pole waterwheel generators

Lowering the rotor into the second alternator at the Fionnay Power Plant in Switzerland, owned by the Forces Motrices de Mauvoisin, S.A., Sion, where three generators rated 60 MVA, 0.8 p.f., 750 r.p.m., 10.5 kV, 50 c/s are being installed.

Some high-speed waterwheel generators at present under construction, or recently installed:

No. of Units	Output kVA	Shaft	Speed r.p.m.	Power Station	Country
1	23 000*	V	1 000	Oberaar	Switzerland
2	20 000	H	1 000	Ernen	Switzerland
3	60 000	V	750	Fionnay	Switzerland
3	29 000	H	750	Motec	Switzerland
1	30 000	V	750	Piottino	Switzerland
3	57 500	V	720/600	Tingambato	Mexico
1	60 000	V	600	Paradela	Portugal
2	45 000	V	600	Hemsil II	Norway
3	17 650	V	600	Neriamangalam	India

* Synchronous motor

BROWN BOVERI

BROWN, BOVERI & CO., LTD.
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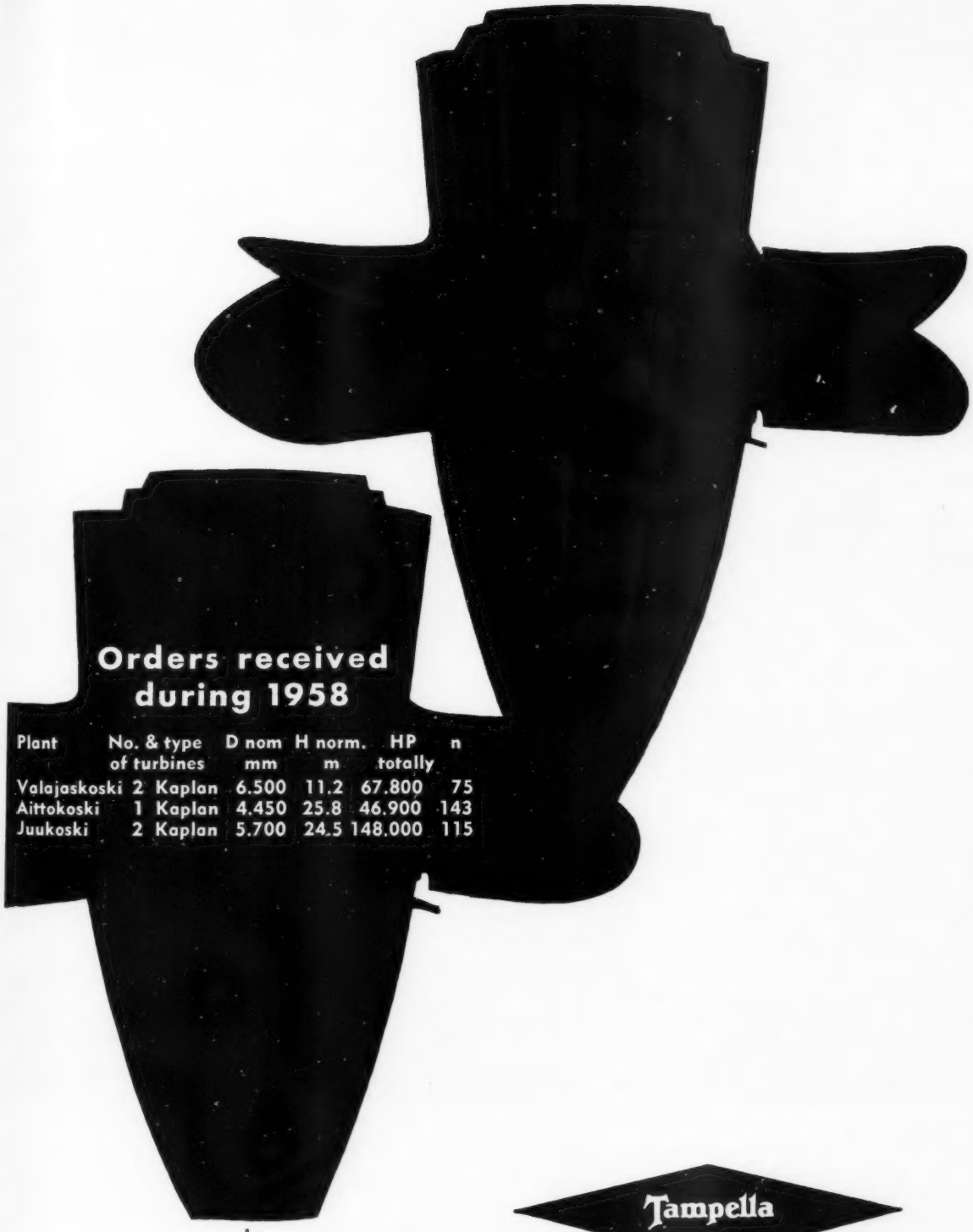
Representatives in most countries



Orders received during 1958

Plant	No. & type of turbines	D nom mm	H norm. m	HP totally	n
Valajaskoski	2 Kaplan	6.500	11.2	67.800	75
Aittokoski	1 Kaplan	4.450	25.8	46.900	143
Juukoski	2 Kaplan	5.700	24.5	148.000	115

Tampella

TAMMERFORS LINNE-OCH JERN-MANUFAKTUR
AKTIE-BOLAG ENGINEERING WORKS

ESTABLISHED 1842

TAMMERFORS, FINLAND

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COCKBURNS non-return SWING CHECK VALVE

- *Counterpoise device minimises Slamming action.*
- *Separate valve facing permits positive shut off and easy renewal.*
- *Minimum Pressure Drop*

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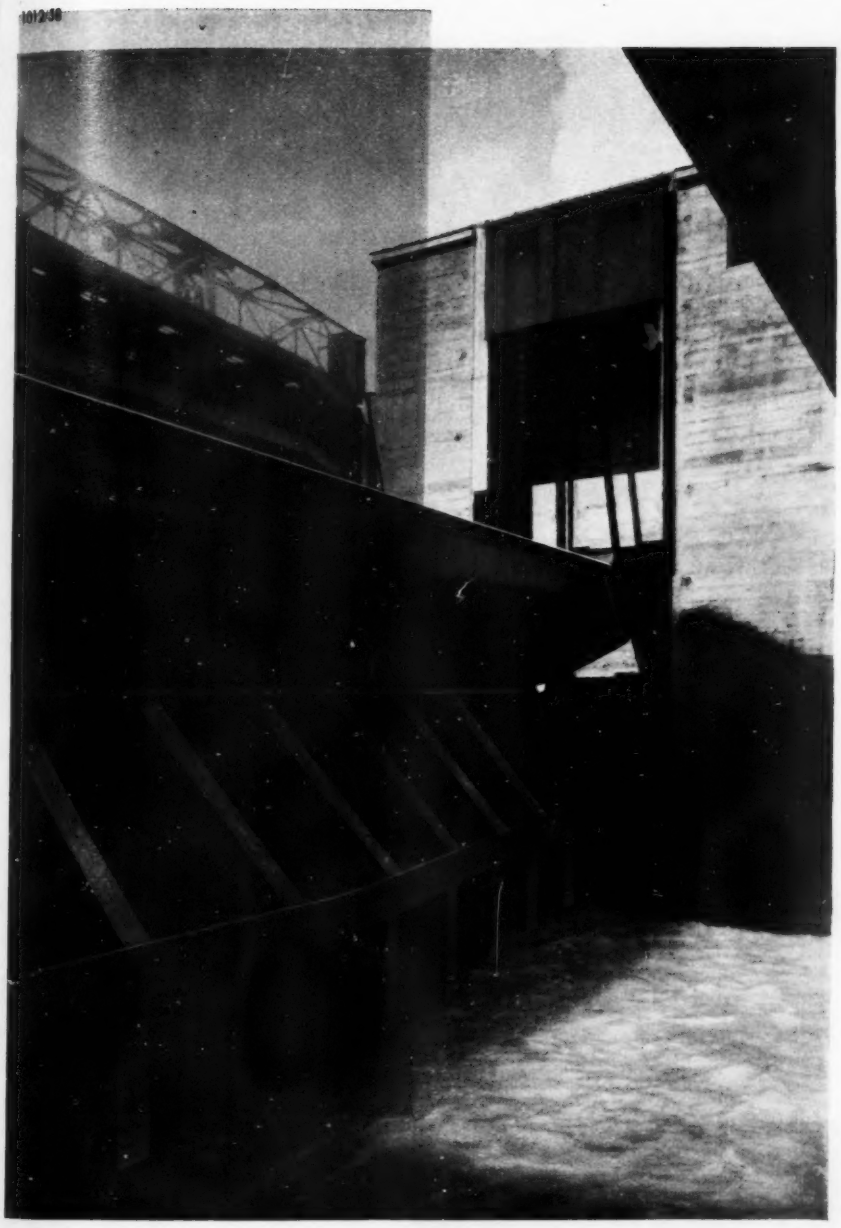
COCKBURNS (NEDERLAND) N.V.
Kethel, Schiedam, Holland



M·A·N

For hydro-electric plants fine regulation of the water level is important. This is best achieved by discharging the up-stream water over the gate. Particularly suited for that purpose is the M. A. N. Flap Gate. A remarkable plant is the power station, shown in the picture, in the River Inn at Neuötting, with 5 gates of 18 m clear width and 8.5 m height each, height of flap 2.2 m.

HYDRAULIC STRUCTURES

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIES

★ The illustration shows a Horseley - Piggott Pressed Steel Tank which was supplied to the Dearne Valley Water Board.

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The Horseley Group offers a wealth of experience and extensive facilities to meet the most exacting demands of Constructional, Chemical, Civil, Gas and Water Engineering.

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HORSELEY PIGGOTT LTD
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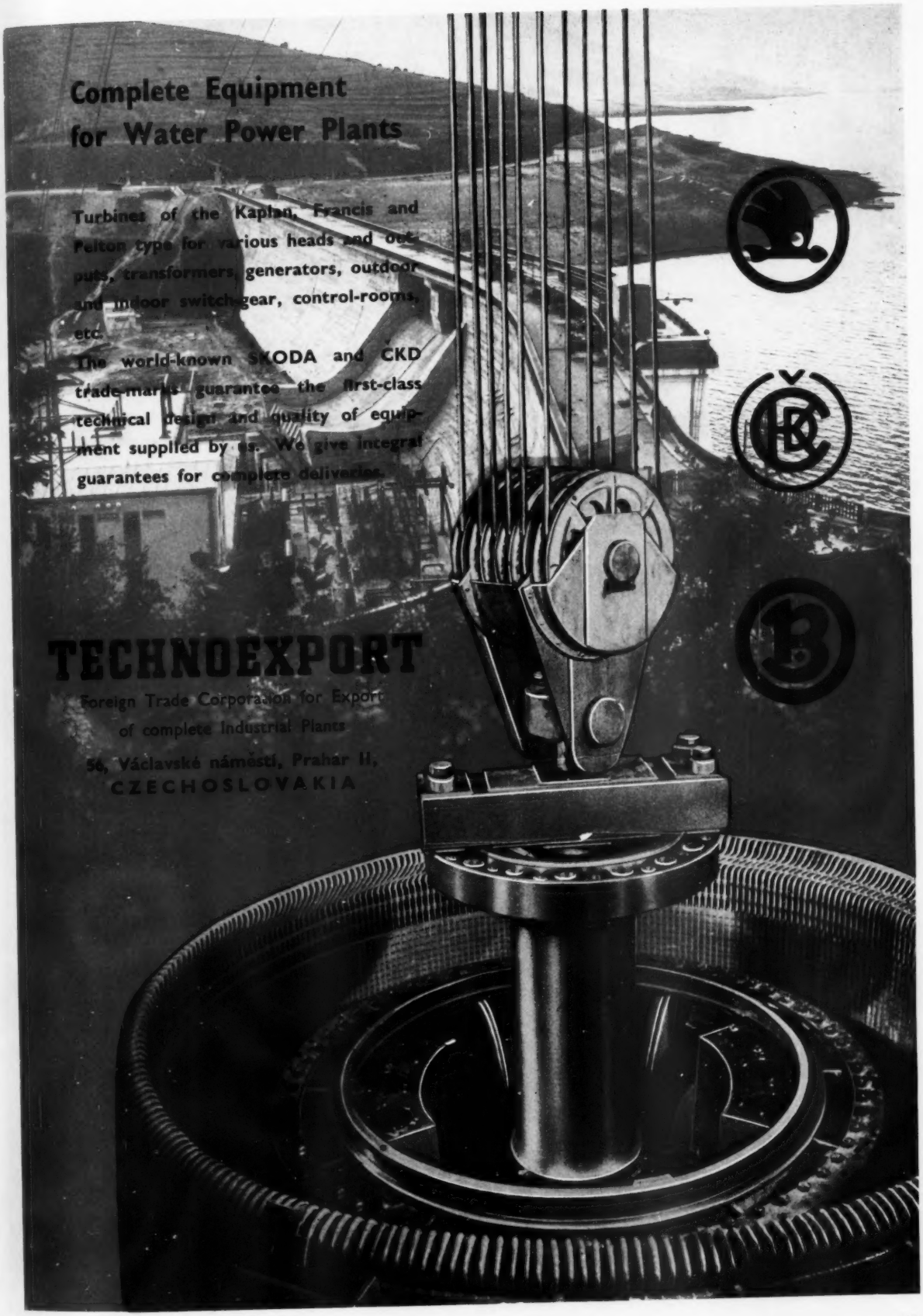
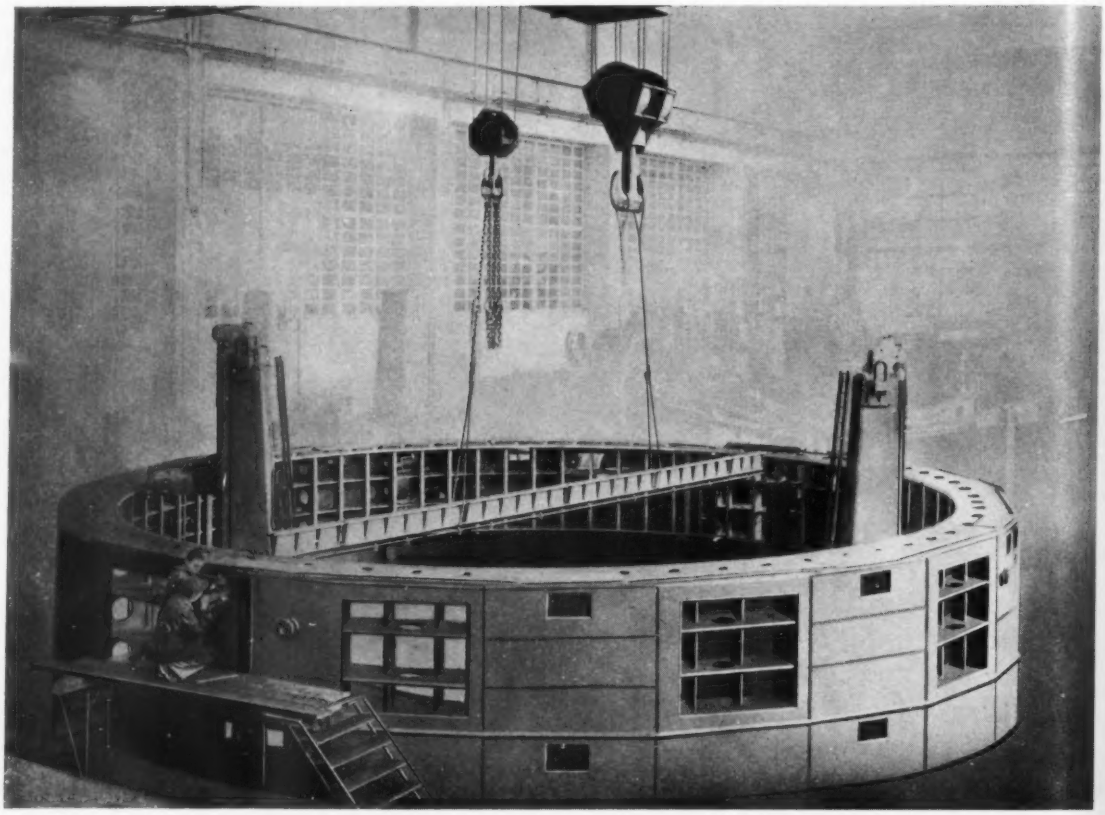

Complete Equipment
for Water Power Plants
Turbines of the Kaplan, Francis and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switchgear, control-rooms, etc.
The world-known SKODA and CKD trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries.
TECHNOEXPORT
Foreign Trade Corporation for Export of complete Industrial Plants
56, Václavské náměstí, Prahar II,
CZECHOSLOVAKIA

LOW-SPEED WATER-WHEEL-DRIVEN GENERATORS



Measuring the bore on the casing of a 50-MVA umbrella-type generator, 75 rpm, for Järkvissle Power Station of the Swedish State Power Board. Bore: 12 m (39 ft.). Outside diameter: 14 m (46 ft.)

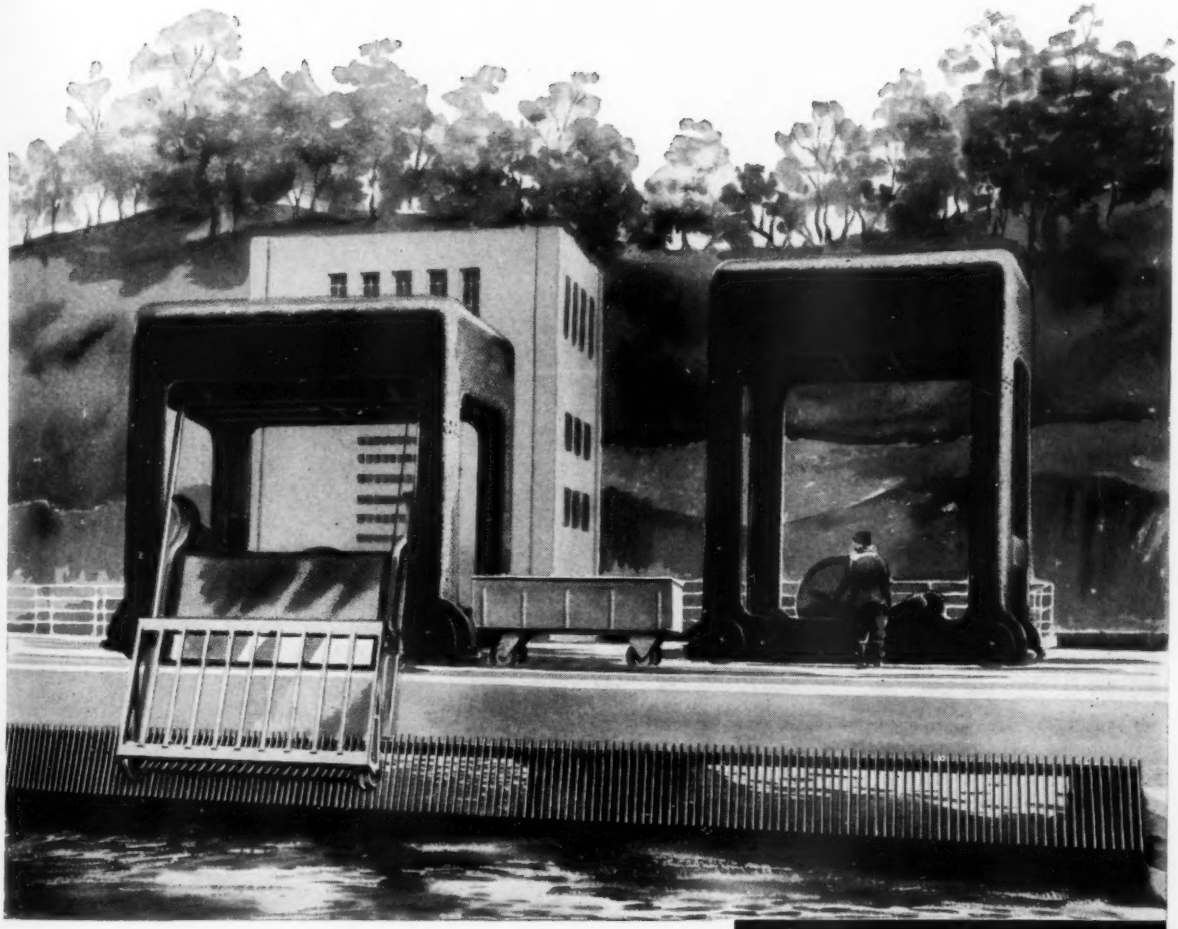
ELIN-UNION

Aktiengesellschaft für elektrische Industrie

Vienna - Austria

All types of

mechanical handling plant



. . . screens, trash rakes and cranes for hydro-electric intake works . . .

Strachan and Henshaw Ltd

STEELHOIST WORKS
BRISTOL 2 ENGLAND
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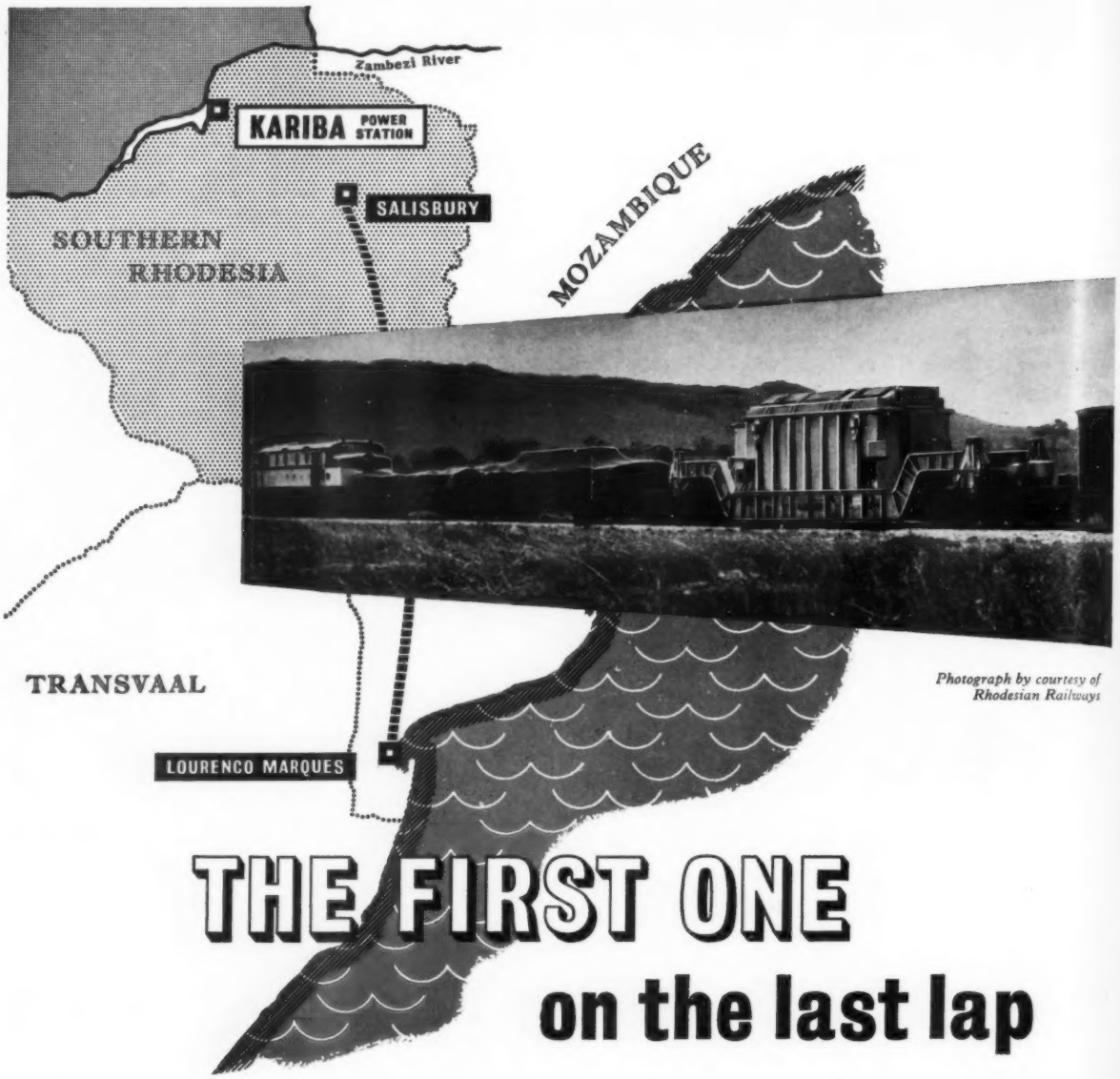

Photograph by courtesy of Rhodesian Railways

THE FIRST ONE
on the last lap

The first 60,000 kVA 330/33 kV 3-phase double wound transformer en route from Lourenco Marques to Salisbury Sub-Station, for the Kariba Hydro-Electric Scheme.

This forms part of the contract awarded to Ferranti Ltd. by the Federal Power Board, Rhodesia and Nyasaland, comprising two 120,000 kVA 330/234 kV 3-phase auto transformers with series boosters, nine 60,000 kVA, 330/88 kV and two 60,000 kVA, 330/33 kV 3-phase double wound transformers.

The consulting electrical & mechanical engineers are Messrs. Merz & McLellan.

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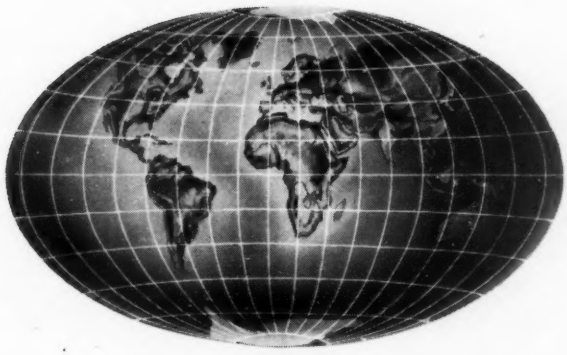
Water Power Experts
all over the World
rely on Steel Castings and Forgings
made by Bochumer Verein



Our production programme for hydraulic power plants includes:

Forged steel shafts for pumps and turbines.

Runners for impulse and Francis turbines, up to the largest dimensions, in plain carbon or 13 % chromium cast steel.

Kaplan runner blades and runner hubs, spiral casings, stay rings, regulating rings, guide vanes etc.

Spherical valve housings, valve bodies, butterfly valve discs and housings, annular valve housings.

Single and double pump wheels, also in 13 % chromium cast steel, up to the largest dimensions.

Guide wheels, suction bends, etc.

Most highly stressed forgings and castings are made of our BV-Vacuum Steel.

BVG

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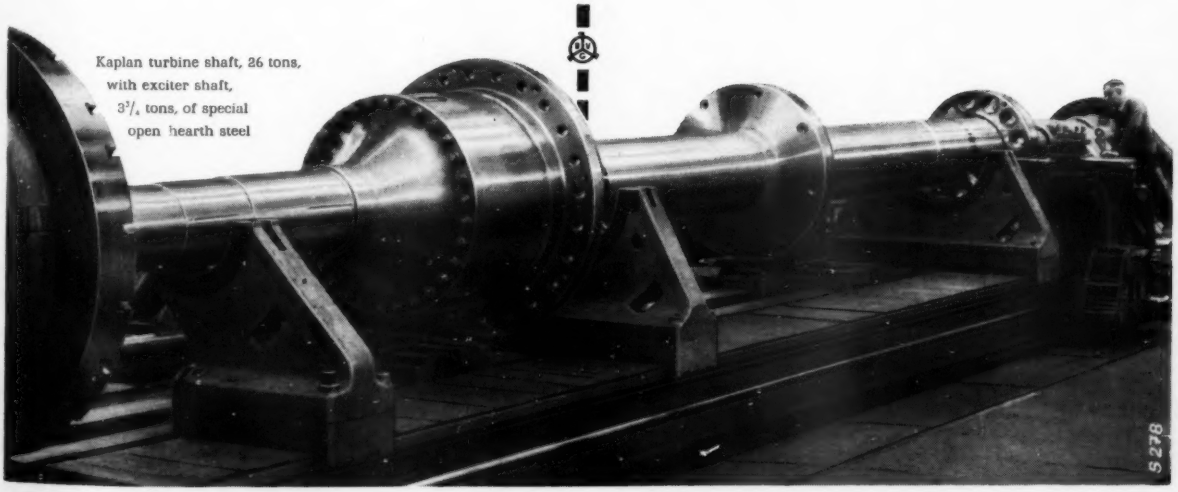


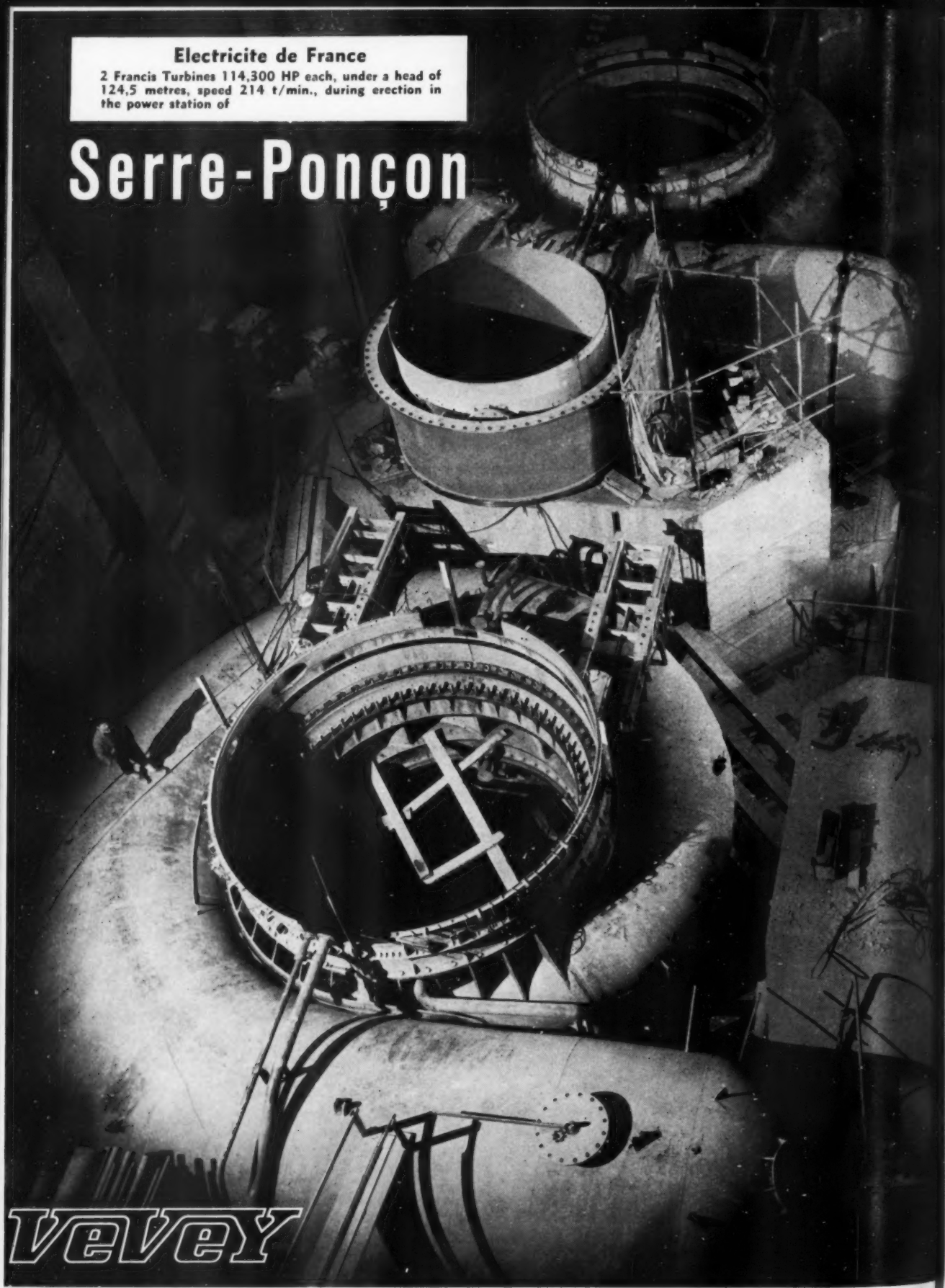
Kaplan turbine shaft, 26 tons, with exciter shaft, 3⅞ tons, of special open hearth steel

S 278

Electricite de France

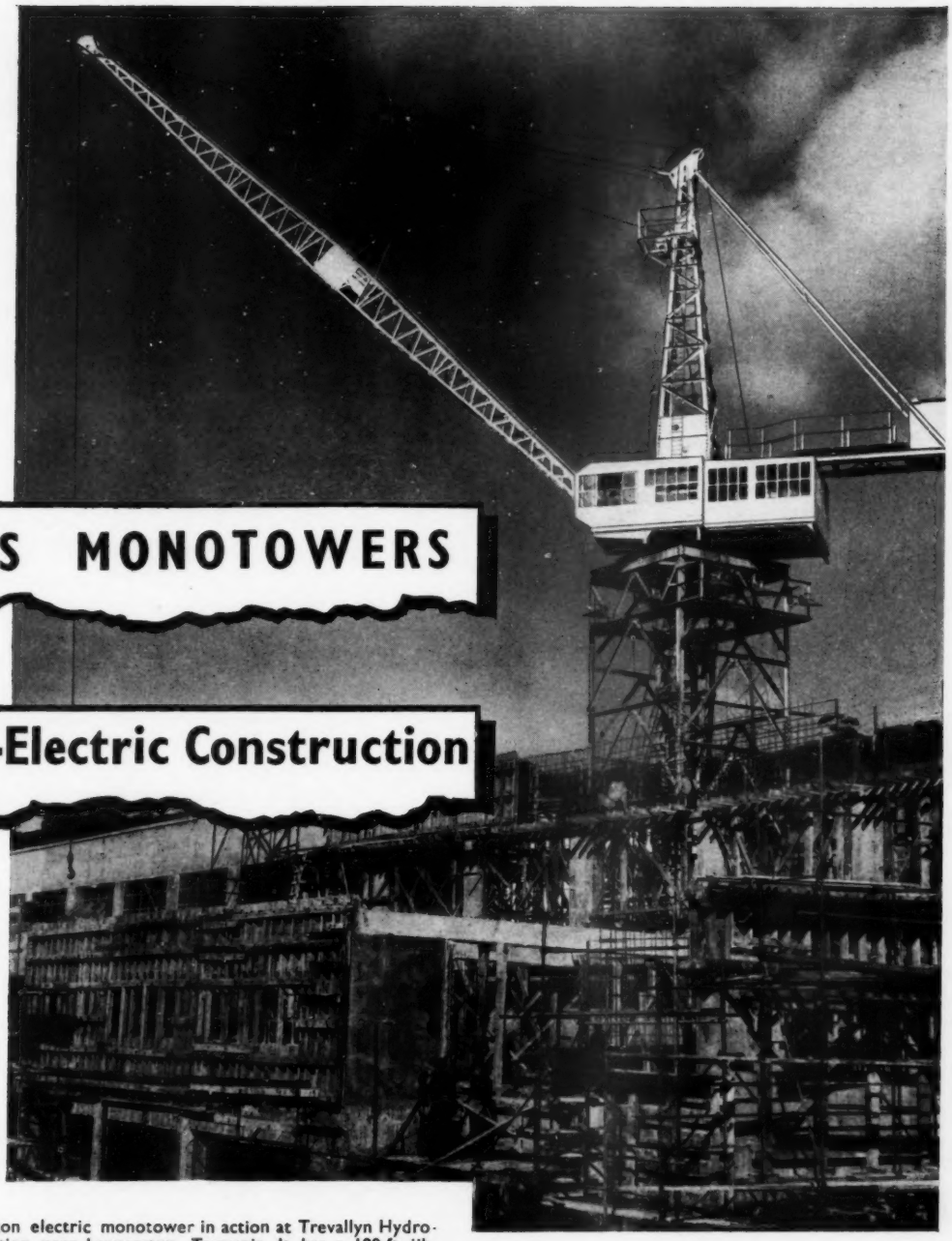
2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

Serre-Ponçon



Vevey Engineering Works Ltd.
Vevey (Switzerland)

in collaboration with our French licensee:
Cie des Ateliers et Forges de la Loire, St-Chamond (Loire)



BUTTERS MONOTOWERS

in Hydro-Electric Construction

This crane is a 5 ton electric monotower in action at Trevallyn Hydro-Electric Power Station near Launceston, Tasmania. It has a 100 ft. jib, 80 ft. tower, and handles 5 tons at 75 ft. and 1¼ tons at 100 ft. radius. The ideal crane for erection of dams and high buildings generally, with all the dependability of the Butters product.

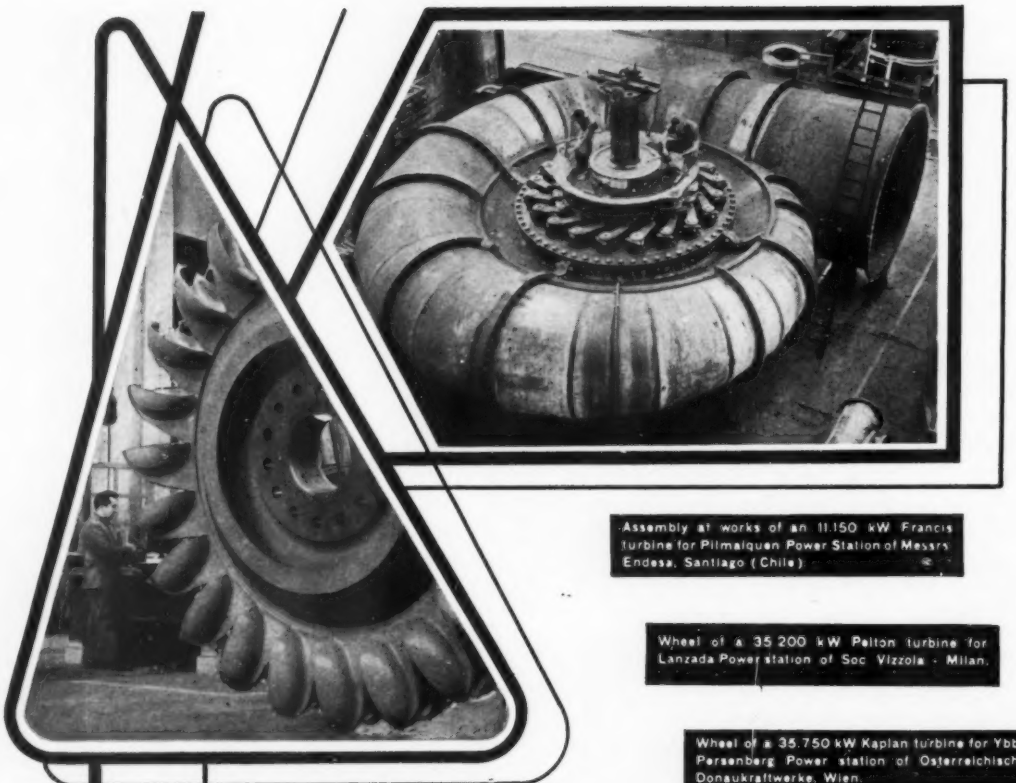
BUTTERS BROS. & CO. LTD.

MACLELLAN STREET, GLASGOW, S.1.

Telephone: IBROX 1141 (6 lines) *Telegrams: "BUTTERS, GLASGOW."*

AND AT LONDON, BIRMINGHAM & NEWCASTLE

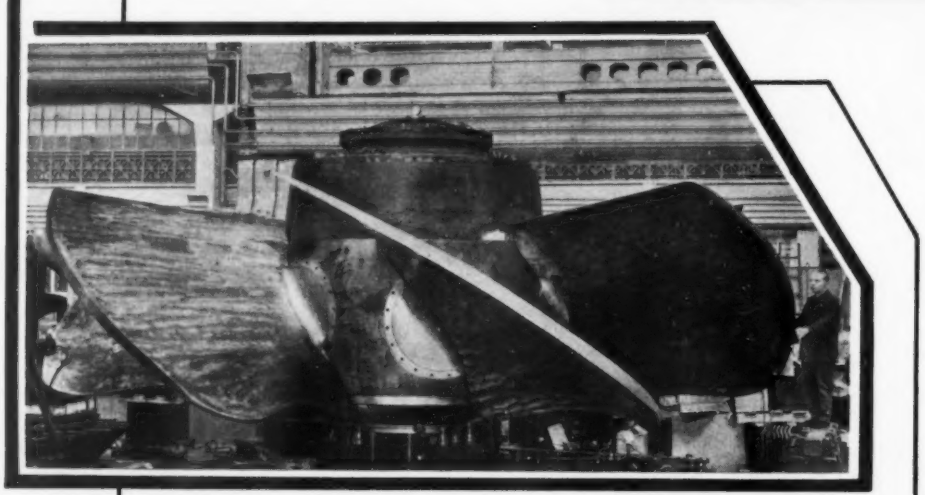
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmaiquen Power Station of Messrs Endesa, Santiago (Chile)

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
GENOVA

HITACHI

CONVERTIBLE SHOVEL

There's little glamour about a machine designed for engineers by engineers—men who are unsatisfied with anything less than constant, top efficiency. On Burma's big Balu-chang Power Station construction project, where excessive down time for maintenance or repairs could seriously disrupt the work schedule, the machines must be no less tough than the men who drive them.

The rugged HITACHI Convertible Shovel has been built for smooth and fast operation under the toughest conditions, from the tips of its wear-resistant cast steel dipper teeth to its stable, extra long and wide truck frame. The versatile HITACHI Convertible Shovel offers a choice of diesel engine or electric induction motor as prime mover, can be mounted on crawlers or truck for still higher mobility. The efficient HITACHI Convertible Shovel converts quickly and readily to dragline, drag shovel, clamshell, crane or piledriver.

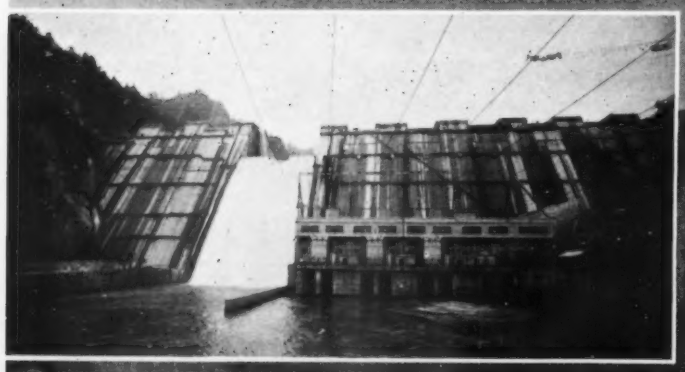
Literature and quotations gladly supplied on request.

Hitachi, Ltd.
Tokyo Japan

Cable Address: "HITACHY" TOKYO

MITSUBISHI

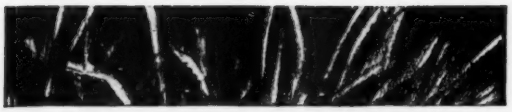
means QUALITY PLUS INTEGRITY



Mitsubishi Electric has again demonstrated its superiority in production capacity and technical skill by completing 3 SETS of 105,000 kVA umbrella type water-wheel generator—the largest of its type ever produced in Japan.

MITSUBISHI ELECTRIC MANUFACTURING COMPANY

Head Office: Tokyo Building, Marunouchi, Tokyo Cable Address: MELCO TOKYO

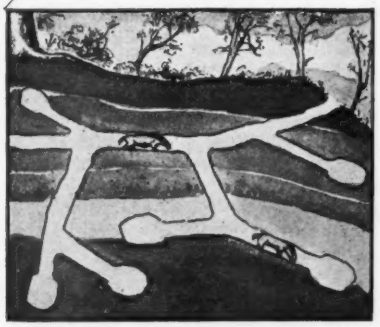


Underground movement

A long tunneller and a strong tunneller, the badger builds himself an intricate web of passages and dens in which to evade pursuit or retire from the noisy world outside.

It's a paradox of progress that man too—in getting even further away from nature—is going more and more underground. Tunnels for hydro-electric schemes, underground power houses—these and many other engineering feats are the work of man the tunneller—a skill which we have developed into a fine art. * *

* * In driving 40 miles of tunnels for the North of Scotland Hydro-Electric Board, Mitchell Construction captured and hold the World high speed rock-tunnelling record and constructed the first major underground power station in Britain.



Many of these badger 'sets' have been enlarged and improved through successive generations and may extend for hundreds of feet into a hillside.

MITCHELL CONSTRUCTION

Building and Civil Engineering Contractors

THE MITCHELL CONSTRUCTION COMPANY LIMITED

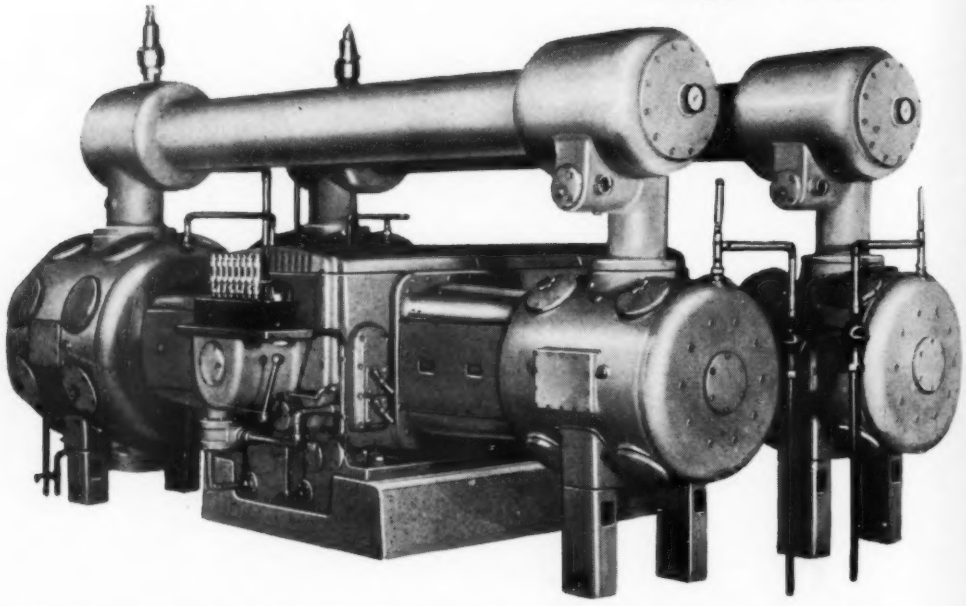
WHARF WORKS · PETERBOROUGH

P.2784

If you are in the

the standard **"FE"** compressor units
can be assembled to suit your exact
requirements for AIR AT LOWER COST

Class "FE" compressors are suitable for handling gasses other than air.



The advantage of standard Consolidated Pneumatic "FE" class compressor units is that they can be built up into single or multi-stage installations giving outputs up to 5,000 c.f.m. or pressures up to 3,000 p.s.i. to suit *exact individual* requirements, thus giving the most efficient return in terms of air delivered for power consumed. And, because the machines consist of standard units, the basic engineering cost of the plant as a whole is lower. Further, the virtues of the balanced-opposed design of these units are such as to effect considerable savings in foundation work, floor space and maintenance costs. In every way, "FE" compressors mean air at lower cost.

A Consolidated Pneumatic four-cylinder, four-crank, two-stage, double-acting horizontal balanced-opposed Class FE-42 Compressor. This unit requires 650 H.P. and delivers 3600 c.f.m. at 100 p.s.i. working pressure.

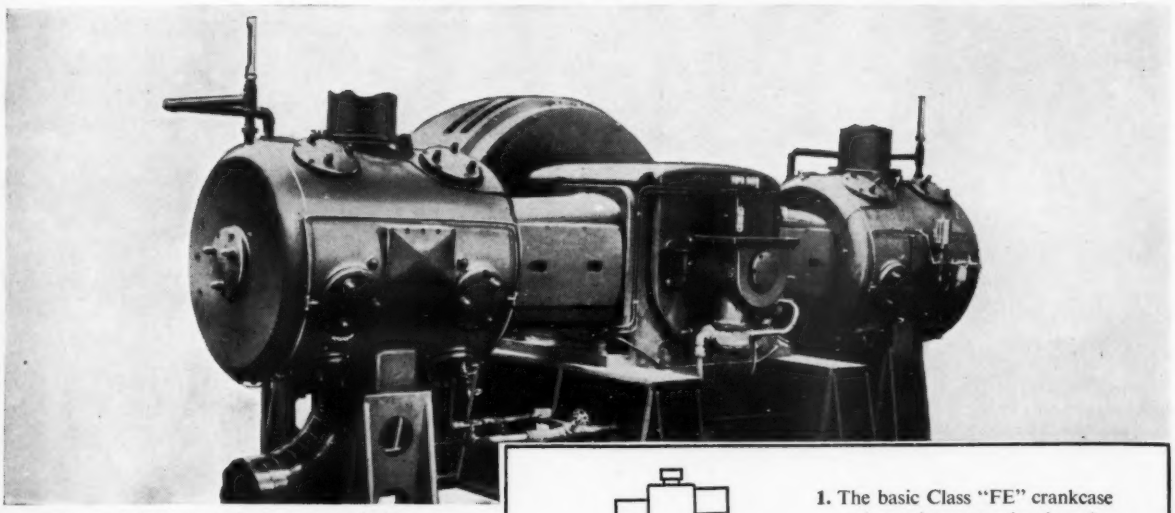
Consolidated Pneumatic CLASS **"FE"**

MAKERS OF AIR COMPRESSORS AND 480 DIFFERENT MODELS OF POWER TOOLS

CONSOLIDATED PNEUMATIC TOOL CO LTD · DAWES ROAD

big-user class*

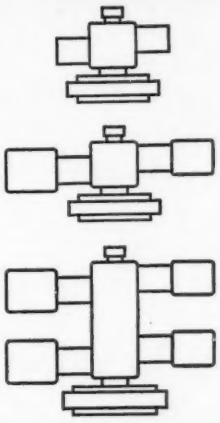
*** up to 5000 c.f.m. or 3000 p.s.i.**



A two-cylinder, two-crank, single-stage, double-acting, horizontal balanced-opposed Class FE-21 Compressor. This unit requires 300 h.p. and is designed for 2500 c.f.m. at 40 p.s.i. Picture shows plant on the test bed in the Consolidated Pneumatic works, Fraserburgh, prior to delivery for operation by Charles Brand & Son Ltd., on the Clyde Tunnel contract.

ADVANTAGES OF THE BALANCED-OPPOSED DESIGN

In the "FE" compressors, the crankcase and frame are centrally positioned with cylinders on opposing sides, the drive being obtained by a double-throw crankshaft. The resulting perfect dynamic balance makes for far greater compactness and virtual freedom from vibration, space and foundation work being reduced to a minimum. Also, the considerably smaller load imposed on main bearings, together with slow operating speed, ensure an extremely long life of continuous operation with very little maintenance.



1. The basic Class "FE" crankcase and running gear, showing also compactness achieved by using engine-type, salient-pole motor.
2. Different-size cylinders can be fitted, one-, two-, three- or four-stage machines being available.
3. Large outputs are obtained by increasing the number of cylinders and working off a common crankshaft.

For further information complete this form and pin it to your letter heading.

No. 40

This form will bring you a descriptive catalogue on Class "FE" Compressors, but if you would like advice on a projected plant, your enquiry can be dealt with more expeditiously if the following information can be provided:

1. Output required in cubic feet per minute at intake pressure and temperature. .....
2. Intake temperature and humidity. .....
3. Intake pressure. .....
4. Discharge pressure. .....
5. Type of drive motor, voltage, etc. .....
6. Temperature of cooling water and type of cooling circuit. .....
7. Aftercooler, if required, and temperature of air at discharge from aftercooler. .....
8. Purpose for which compressor is to be used. .....

CP165

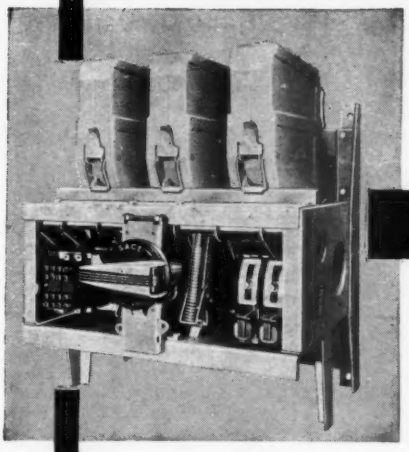
COMPRESSORS

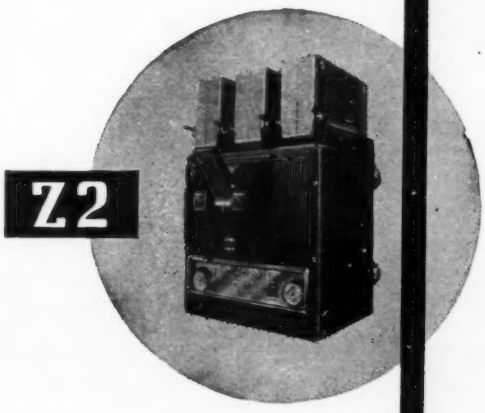
LONDON · SW6

KVÆRNER
Now under construction—Four turbines
for Tokke 1 Power Plant, Norway.
Head - - 395 metres (1,200 ft.)
Output - - - - - 150,000 H.P.
Revolutions - - - - - - - - 375
Weight of Spiral Casing 110 tons
A. S. KVÆRNER BRUG, OSLO, NORWAY

UPT - SACE 120

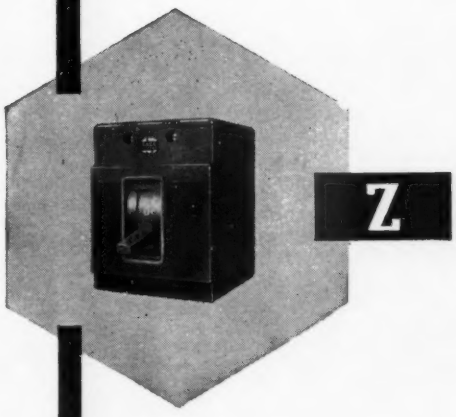
Circuit-Breaker type "P"
Rated voltage 600 V
Rated current up to 4,000 A
Breaking capacity up to 55 kA
up to 500 V a.c.





Circuit-Breaker type "Z 2"
Rated voltage 600 V
Rated current up to 600 A
Breaking capacity up to 20 kA
at 500 V a.c.

Circuit-Breaker type "Z"
Rated voltage 500 V
Rated current up to 150 A
Breaking capacity up to 12 kA
at 500 V a.c.



S.p.A. COSTRUZIONI ELETTROMECCANICHE SACE BERGAMO **BERGAMO**

Head Office and Works
Bergamo - Via Baioni, 35

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ITALY

In Turkey . . .
and the world over

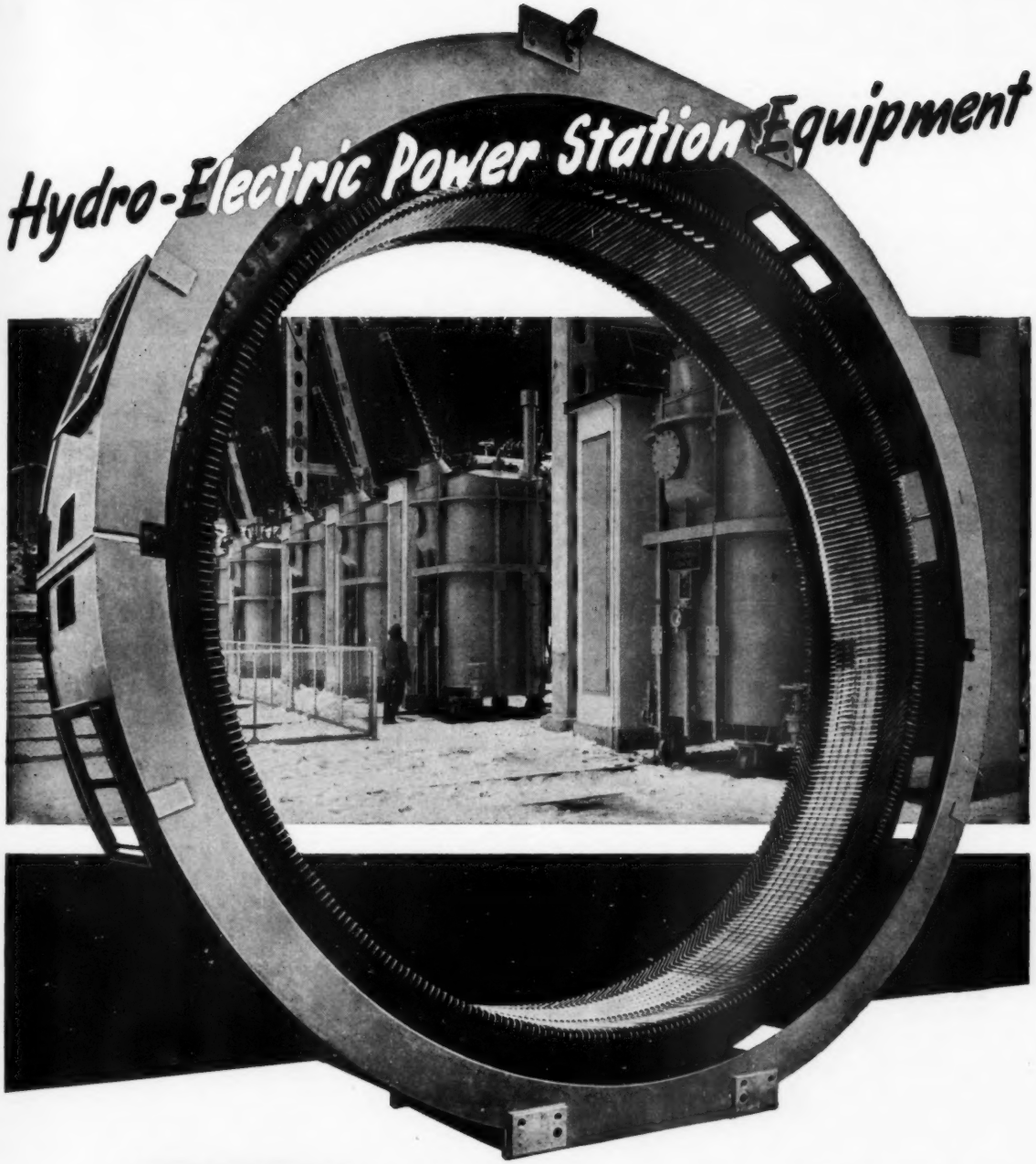
Bucyrus-Erie excavators are identified with progress

Whatever its form, the development of resources for a nation's progress begins with excavation. But hand excavation is slow and costly and today large schemes are only practical because of the advantages of modern large-scale mechanical excavation whether it be in open-cast mining or public works. Hydro-electric power schemes to utilise the natural resources of a country involve the excavation of immense quantities of earth and rock. Shown are two of the five 54-B machines used by Association EMC-RAR on dam construction work at Demirköprü. The Hydraulic Works Administration justifiably put their faith in Bucyrus-Erie.

BUCYRUS ERIE

BUCYRUS-ERIE COMPANY
South Milwaukee, Wisconsin, U.S.A.
RUSTON-BUCYRUS LIMITED, LINCOLN, ENGLAND

Hydro-Electric Power Station Equipment



Sécheron

Generators and motors with capacities above 150 kW. Single-phase and three-phase transformers for all outputs and voltages. Electrical applications in the field of traction. Installations of pumpless mercury arc rectifiers with rare gas filling. High-speed automatic regulators applied to various control problems. Welding rods and electric arc welding sets.

S.A. des Ateliers de Sécheron, Geneva

1947 TO 1958

EXTRACTS FROM OUR REFERENCE LIST

44,948 TONS OF PENSTOCKS

DESIGNED · SUPPLIED · ERECTED

Serial No.	Name of Plant and Country		Head in m	Weight in tons	Diameters in m/m	Length in m	Plate thickness in m/m	No. Lines	When ordered
261	Grønsdal	Norway	177	302	2200—1900	255	12—23	1	1947
262	Dale III	,,	311	737	2000—1400	700	12—35	1	,,
263	Grytten	,,	424	374	900—800	1070	8—22	1	,,
264	Maudal II	,,	370	889	1650—1450	900	12—30	1	,,
268	Skjerka II	,,	340	1502	2100—1650	1240	22	1	,,
272	Sand	,,	320	181	500—450	1650	7—10	1	,,
273	Søre Sunnmøre	,,	377	235	1100—850	682	9—23	1	,,
275	Glomfjord (Flow Lines)	,,	—	368	550	3037	7	1	,,
277	Pykara IV	India	936	3000	1067—991	3025	12—49	1	,,
283	Lund	Norway	251	190	700—550	1112	8—10	1	1948
284	Vadheim II	,,	313	222	1050—850	676	9—17	1	,,
286	Festa	,,	210	194	1300—1200	407	10—14	1	,,
288	Kåven	,,	117	180	1600—1500	360	10—12	1	,,
290	Vinstra I	,,	447	1020	2400—2200	387	14	1	1949
291	Tafjord	,,	400	400	1750	608	8—14	1	,,
292	Åbjøra	,,	439	739	2300—900	666	12—35	1	,,
293	Poringalkuthu	India	181	2000	2590—1320	887	11—30	3	,,
294	Machkund	,,	260	1450	1600—1450	500	11—32	3	,,
298	Sueva I	Colombia	233	88	800—100	514	5—10	1	1951
299	Sueva II	,,	187	135	1200—1000	509	6—12	1	,,
302	Trevallyn	Tasmania	163	470	4420—1727	152	24	1	1952
304	Aura II-C	Norway	295	396	2200	416	12—44	1	,,
305	Aura II-D	,,	744	1112	1600	1212	12—44	1	,,
306	Røssåga	,,	247	1237	3400—3000	398	13—26	2	1953
309	Nore	,,	368	337	1800—1300	475	12—34	1	1954
313	Mocorongo	Colombia	331	657	2000—1736	1015	9—21	1	,,
316	Hardeland	Norway	322	272	1300—1000	879	8—15	1	1955
319	Poringalkutha	India	181	480	2590—1320	887	11—30	1	,,
320	Hjartdøla	Norway	587	1061	2600—1500	1145	10—49	1	1956
321	Machkund 2nd Stage	India	260	1500	1600—1450	500	11—32	3	,,
322	Bhakra (Bulk Heads)	,,	—	60	4450	—	17,5	—	,,
323	Kaldåga	Norway	566	789	1300—1000	1803	8—23	1	,,
329	Sande	,,	90	225	600	3000	5	1	,,
332	Gjuva	,,	390	206	1200—800	875	8—14	1	,,
334	Innset	,,	187	400	3200—2000	253	14—22	1	1957
337	Neriamangalam	India	224	900	3353—1600	1359	12—17	1	1958
338	Kiewa I	Australia	—	5	1912—864	—	20	—	,,
339	Fortun II	Norway	873	112	1600—1300	75	30—61	1	,,
340	Vrenga	,,	379	440	1300—900	1568	8—11	1	,,
341	Tyin II	,,	1009	1485	1600—1200	1857	10—47	1	,,

FERRUM MONTAGE A/S

OSLO · NORWAY

VOITH

RACK-RAKING MACHINES

keep the trash racks free to safeguard the economical operation of the whole power plant. Whether leaves, grass, reeds, branches or trees are involved, VOITH RACK-RAKING MACHINES can cope with any floating debris and trash. The heavy rake readily penetrates heaviest accumulations of floatage in front of the rack. For the disposal of bulky obstructions usually a swivelling outrigger with lifting tongs is fitted as additional equipment. In the photo above, at the left, such an outrigger is visible on the rack-raking machine, while the bottom photo shows the outrigger swung to the rear.

J. M. VOITH GMBH.
HEIDENHEIM (BRENZ) · GERMANY

Henderson

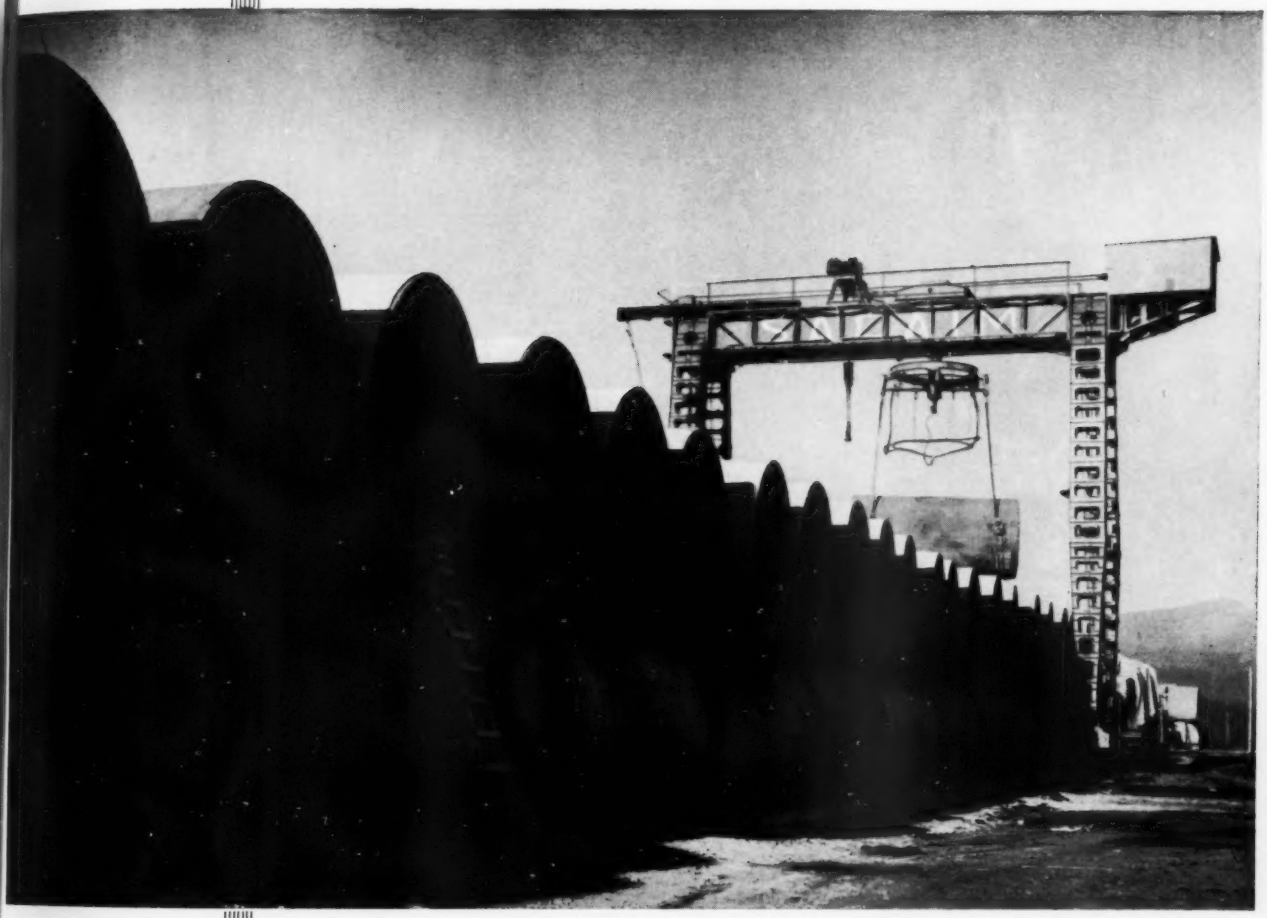
again leads the field in derrick crane design

Wherever there's engineering progress you'll find Henderson Derrick Cranes. The new Henderson Derrick cranes feature unit construction, enclosed gears, ball and roller bearings. Erection and dismantling is faster, control easier, vision better, running smoother and maintenance lower—items which add up to *reduced operating costs!*

raising the standard of World Construction

JOHN M HENDERSON & CO LTD · KING'S WORKS · ABERDEEN · SCOTLAND

Prestressed reinforced concrete penstocks of any diameter and pressure



Main penstock of prestressed reinforced concrete (diameter 6 ft. 7 ins., operating at 440 lb. per sq. in.) made for the Maè-Piave Hydro-Electric station of
S.A.D.E. - SOC. ADRIATICA DI ELETTRICITA'

SACAIM

Soc. p. Az. Cementi Armati Ing. Mantelli

VENICE (ITALY) - Accademia 979/A - Telephone 24.072

Newport News rack rakes . . . minimum-manpower way to keep water intakes free of debris

Newport News mechanical rack rakes are power-operated rakes for cleaning trash racks at water intakes, including those at hydro-electric plants, steam plants, pumping stations, and similar installations throughout this country and abroad. Under ordinary conditions, one man per shift keeps racks clean for a dozen bays.

Operate in channel guides for maximum cleaning action

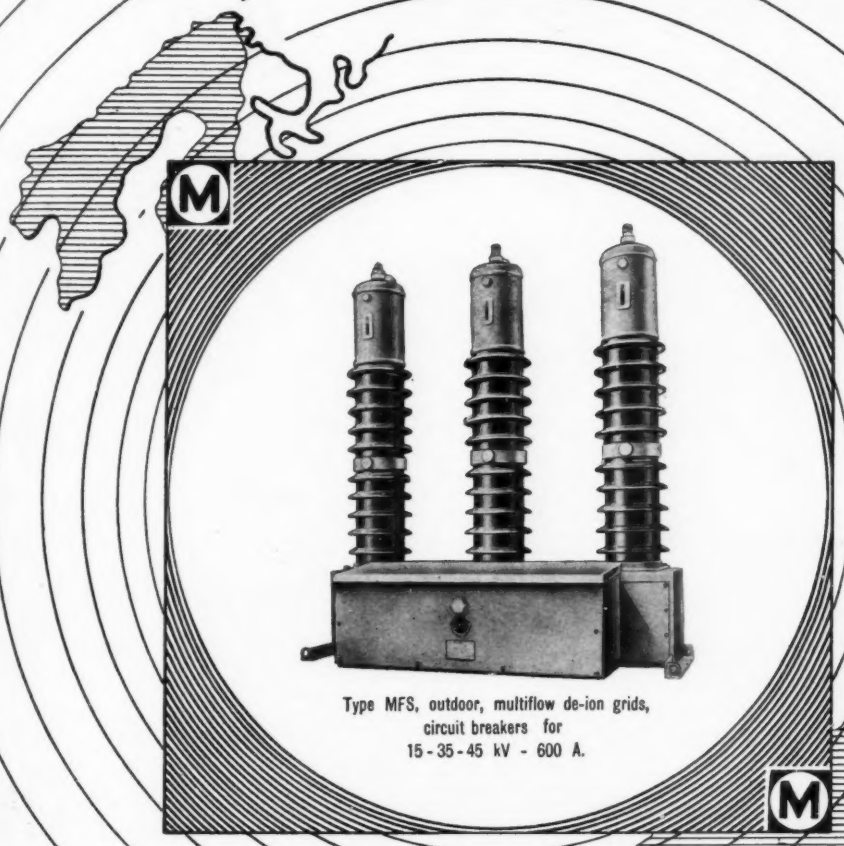
A Newport News rake *won't ride over trash* nor will its teeth drop the debris, because the rake operates in channel guides for positive action. Special teeth are available for cleaning racks of filamentous algae, seaweed, etc.

The Newport News mechanical rack rake has been built to operate in bays from 5 feet 6 inches wide to 28 feet 6 inches in width. Forebay design determines the maximum width for a single rake. In the case of a very wide bay, intermediate guides are sometimes used to reduce the length of the rake. There are many typical installation arrangements to fit your needs. Newport News engineers are prepared to individualize these designs for you.

If you have a debris problem, write for a copy of THE NEWPORT NEWS MECHANICAL RACK RAKE, an illustrated booklet describing the installation, operation, and advantages of a Newport News rake.

Engineers . . . Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News
Shipbuilding and Dry Dock Company
Newport News, Virginia



Type MFS, outdoor, multiflow de-ion grids,
circuit breakers for
15 - 35 - 45 kV - 600 A.

MAGRINI'S TRADE-MARK AND SWITCHGEAR WIN WORLD-WIDE RECOGNITION

MAGRINI S.P.A. - VIA L. MAGRINI 7 - BERGAMO - ITALY

PENSTOCKS, PRESSURE SHAFT LININGS FOR ALL WORKING PRESSURES

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METAL-CLAD SWITCHBOARDS, LINE CP FOR INDOOR AND OUTDOOR, WITH SINGLE OR MULTIPLE BUS-BAR SYSTEM

Rated voltages: 10 - 15 - 20 - 30 KV
Bus-bars rated currents: 600 - 1000 - 2000 Amps
Circuit breaker rated currents: 600 - 1200 - 2000 Amps
Symmetrical breaking capacities: 300 - 600 - 1000 MVA

GLENFIELD
JET DISPERSERS
for points of free discharge

This simple but highly effective device is a valuable aid in solving problems involving the dissipation of the energies in free-discharging high-velocity water jets.

Its use results in the harmless dispersion of the issuing jet without any vibration of the disperser or erosion in the reception area, and renders costly protective works unnecessary.

Glenfield

GLENFIELD & KENNEDY LIMITED KILMARNOCK

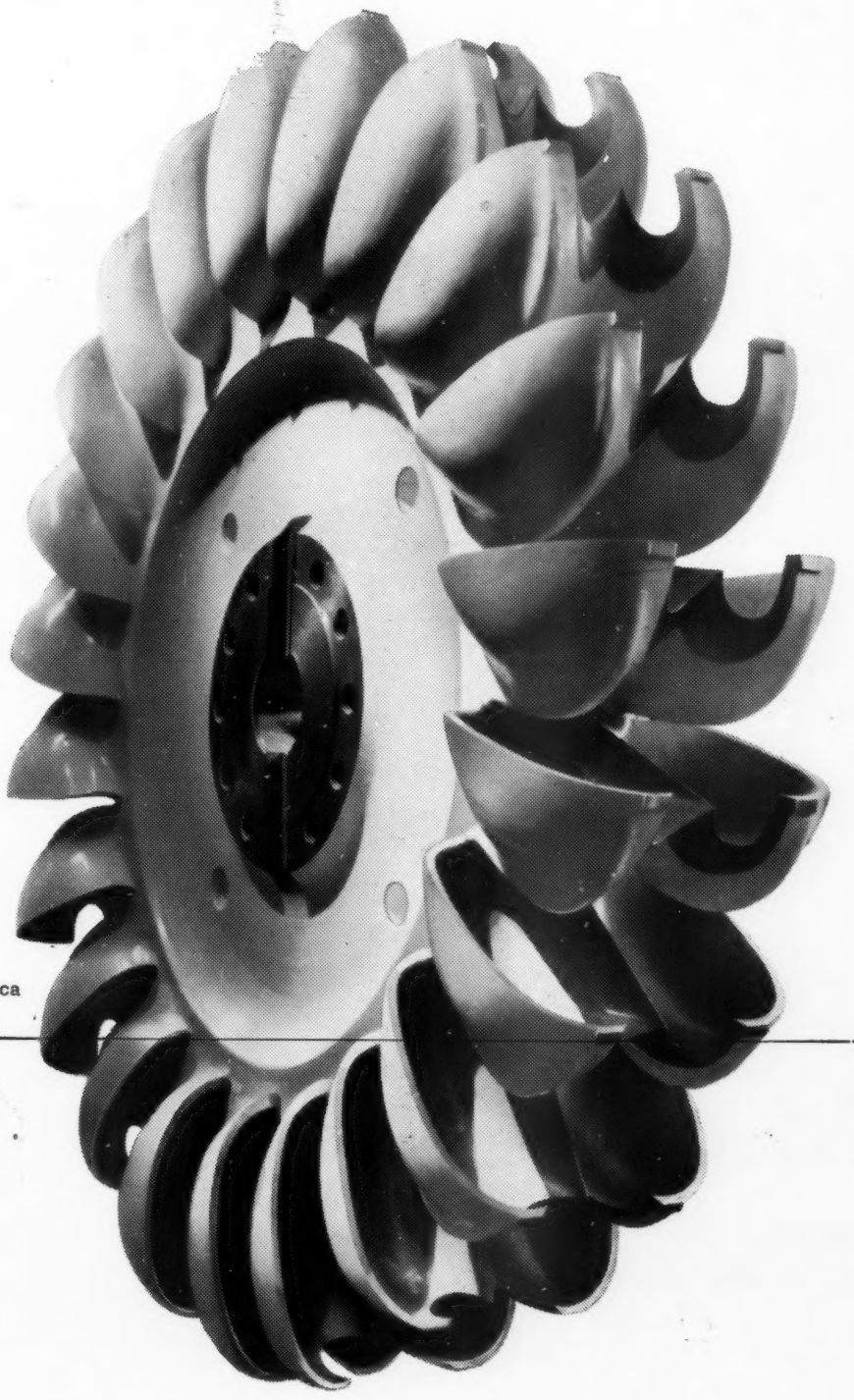
Head Office & Works:
KILMARNOCK, SCOTLAND

ESCHER WYSS

has the following large impulse turbines in course of execution for Swiss installations

	Head in metres	Unit output HP
Castasegna	**710**	**45 000**
Loebbia	**730**	**47 000**
Tavanasa	**480**	**67 000**
Biasca	**700**	**110 000**
Tierfehd	**1030**	**125 000**

Escher Wyss Ltd., Zurich/Switzerland



One of the runners for Biasca

More NEWS from JOY-SULLIVAN!

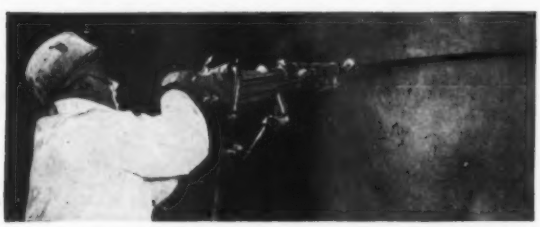
SPEEDLINE

ROCK DRILLS GO INTO ACTION

JOY SULLIVAN introduce the first of a BIG range of compressed air tools in the shape of the SPEEDLINE L.37 and L.47 rock drills. Proved on some of the world's toughest projects, hardhitting SPEEDLINES are now made in Britain and offered for favourable sterling purchase.

good reasons why SPEEDLINES hit hard—bite deep

Exclusive to SPEEDLINE drills, DUAL VALVES supply air at exactly the right moment — on both up and down strokes. Operating independently, DUAL



VALVES give precise 'cushion control' —extract *more* work from the *same* air.

CADMIUM PLATED, SPEEDLINE drills cannot support rust, start easily after long idleness. Plating acts as extra lubricant for faster, smoother operation. Built-in oil reservoir, ... full line-pressure hole blowing . . . one-piece, rubber cushioned steel puller . . . replaceable buffering liner . . . these are some of the advance SPEEDLINE features for better footage and longer life.

SPEEDLINE L37

A 35 lb. class tool with power-to-spare for many applications. On quarry, mine and building site, the L.37 makes light work of it.

SPEEDLINE L47

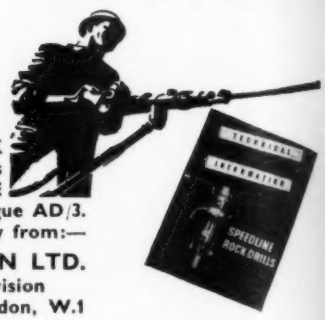
A husky 50 lb. class drill with the performance of many conventional heavyweights, the L.47 drills up to 16 ft. in favourable conditions. For wet or dry drilling.

THE JAL47 AIRLEG DRILL

for maximum footage in mining and tunnelling. One-hand feed control, perfect balance, high penetration speeds with low maintenance costs . . . the Air Leg Rock Drill removes strain from the operator — reduces drilling time, a controlling factor in maintaining good cycle times.

AIR POWER **SUPPLIED & APPLIED BY**

AIR POWER
JOY-SULLIVAN LTD
DIVISION



A GOOD BOOK to have on hand is the SPEEDLINE Rock Drill Catalogue AD/3. Ask for your copy from:—

JOY SULLIVAN LTD.
Air Power Division
7 Harley St., London, W.1

HYDRO-ELECTRIC GENERATORS

Over 50 years ago Bruce Peebles engineered the Snowdon Hydro-Electric Scheme in North Wales—the first large project for public supply in Great Britain.

The pioneering spirit which carried the Company to success in the early days is still dominant and is revealed to-day in the many contracts undertaken for large hydro-electric plant for many schemes at home and abroad.

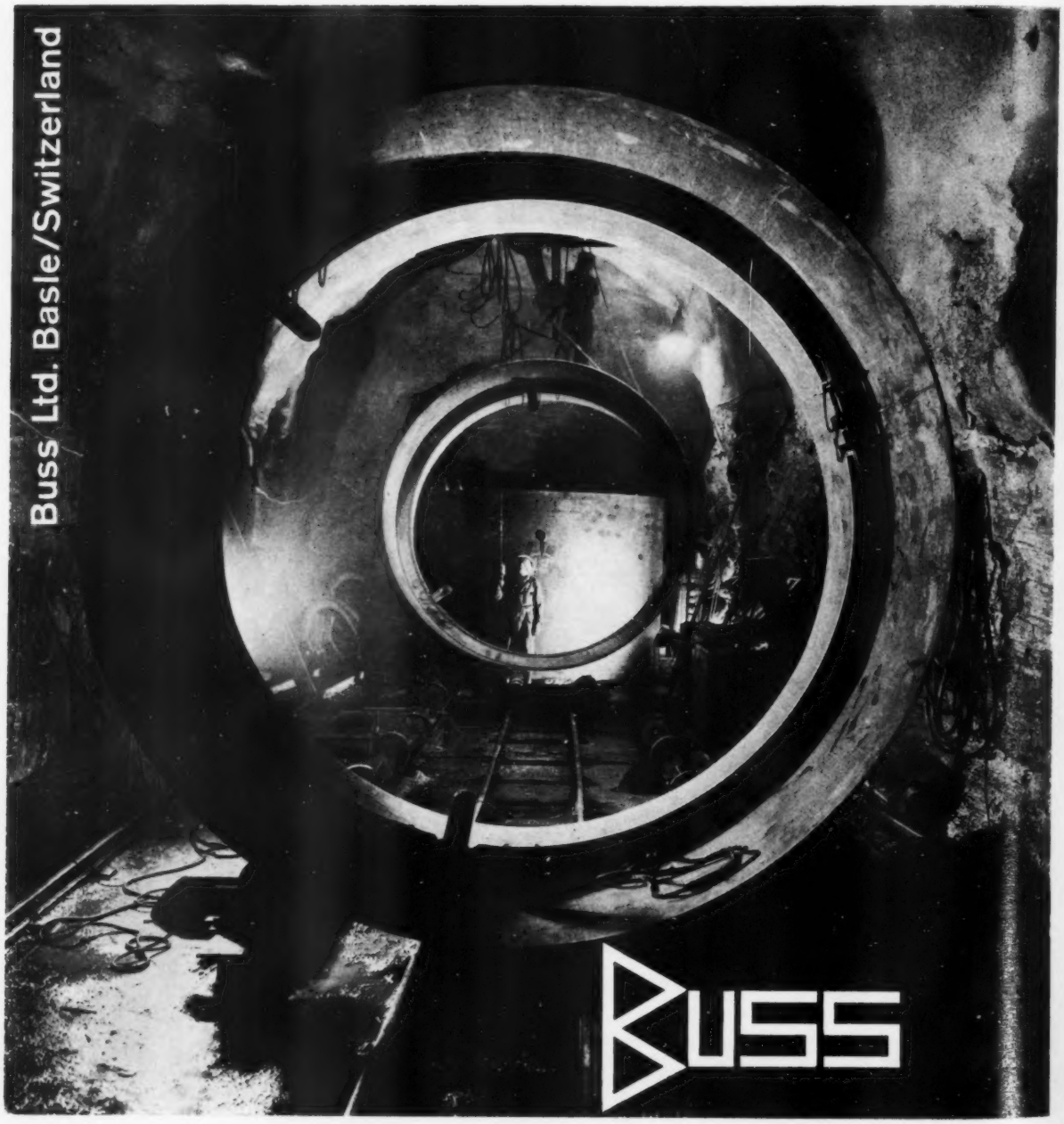
BRUCE PEEBLES EDINBURGH

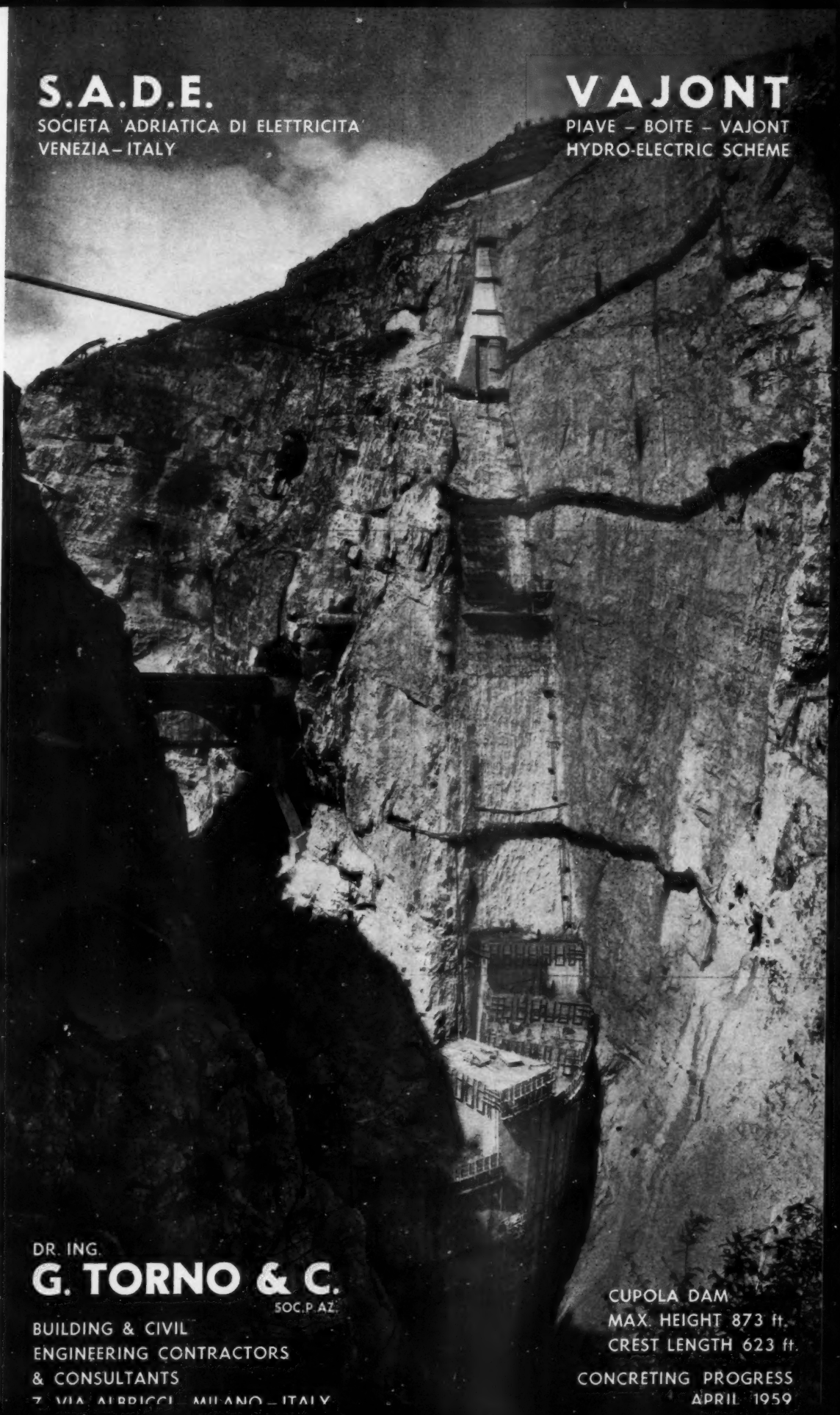
Partially erected 18 MW vertical generator for the Orrin power station of the North of Scotland Hydro-Electric Board.

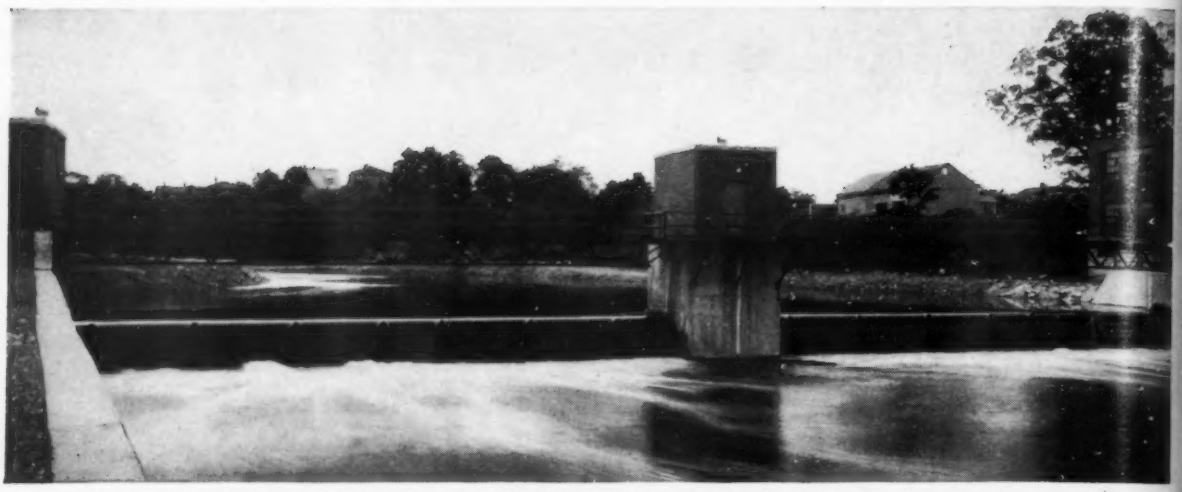
BRUCE PEEBLES & CO. LIMITED, EDINBURGH, SCOTLAND

specialized

in penstocks and pressure shaft linings as well as in other equipment for hydro-electric power plants



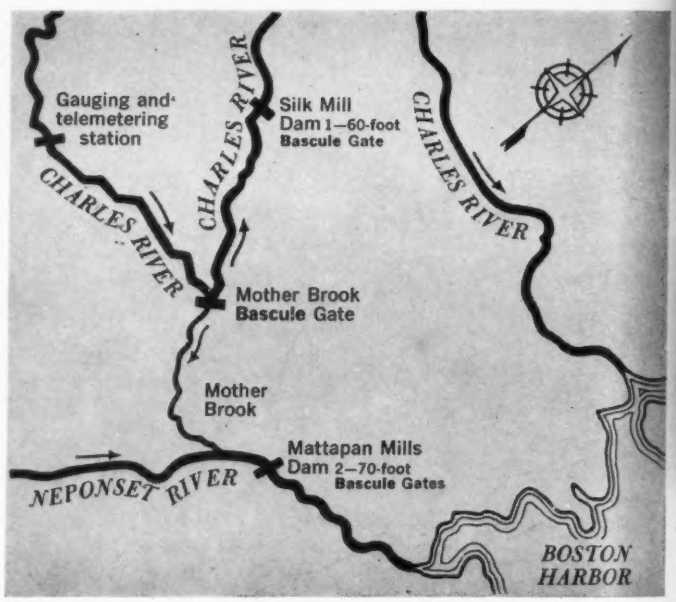

S.A.D.E.
SOCIETA ADRIATICA DI ELETTRICITA'
VENEZIA – ITALY
VAJONT
PIAVE – BOITE – VAJONT
HYDRO-ELECTRIC SCHEME
DR. ING.
G. TORNO & C.
SOC.P.AZ.
BUILDING & CIVIL
ENGINEERING CONTRACTORS
& CONSULTANTS
CUPOLA DAM
MAX. HEIGHT 873 ft.
CREST LENGTH 623 ft.
CONCRETING PROGRESS
APRIL 1959



Two 70-foot by 5.3-foot **Bascule** Gates on the dam at Mattapan Mills operate in echelon. As the river rises, one gate moves down until its full capacity will no longer hold the river level; then the second lowers.

ALLIS-CHALMERS BASCULE GATES

Provide Flood Control and Recreation Facilities on the Charles and Neponset Rivers



Four Allis-Chalmers *Bascule* Gates, installed on the Charles and Neponset Rivers just outside of Boston, provide a unique example of the features of this crest control gate. At Mother Brook, a 30-foot by 3.2-foot gate regulates flow in accordance with a court decree requiring that one third of the flow in the Charles River shall be diverted into the Neponset.

A gauging station, five miles upstream on the Charles, measures flow and telemeters it to a proportioning control unit at Mother Brook. A specially-designed A-C mechanism then adjusts the *Bascule* Gate to divert one third of the flow into the brook.

Bascule Gates at Silk Mill Dam and Mattapan Mills, all longer and higher, maintain pool levels for industrial use and recreational purposes. They also limit flood crests during periods of high flow. For complete information on our standard *Bascule* Gate designs covering a wide range of sizing, contact your A-C office, or write Allis-Chalmers Hydraulic Division, York, Pa.

Bascule and *Rotovalve* are Allis-Chalmers trademarks.

Hydraulic Division — RESEARCH · DESIGN · HYDRODYNAMICS · ENGINEERING · FABRICATION

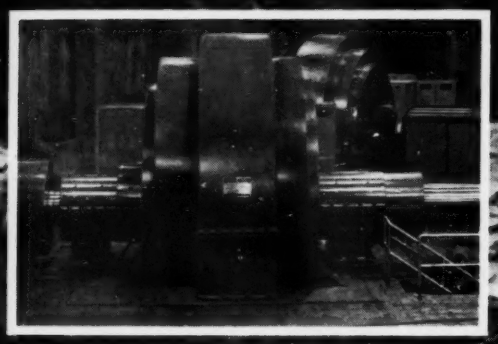
Hydraulic Turbines & Accessories • Pump-Turbines • Pumps • Liquid Heaters

ROTOVALVE • Ball Valves • Butterfly Valves • Free-Discharge Valves

ALLIS-CHALMERS

1109

A REPORT ON POWER FOR PROGRESS



Aerial view of Ambuklao Power Station, largest hydroelectric installation in the Philippines. Inset picture shows underground power station housing 3 General Electric generators.

How a man-made lake and...

General Electric Helped Ambuklao Provide Low-Cost Power For The Philippines

Low-cost electric power is vital to the industrial and economic progress of all nations. In the Philippines, one big step forward has been the completion of the Ambuklao power station in Central Luzon. Here National Power Corporation's highly skilled team of engineers have harnessed the mighty Agno River with its history of flood and devastation, and made it into a peaceful lake that supplies the water for efficient hydroelectric power.

The unique underground power station at Ambuklao houses three General Electric hydro-generators which are a part of the system that provides a combined power output of 75,000 kilowatts. On the same subterranean level with the generator room is the control room where G-E switchboard panels are installed.

Other G-E contributions to the mammoth Ambuklao development include power transformers and carrier-current equipment. All of these products were designed, engineered, produced and tested to meet the highest standards of operating efficiency and reliability.

G-E with vast experience in the electric utility field has installed equipment, under the most adverse circumstances, that benefits government, industry and the people in countries all over the world. Contact your nearest G-E representative for full details about General Electric Power for Progress, or write: *International General Electric Co., Dept. 59-1, 150 East 42nd Street, New York 17, N.Y., U.S.A.*

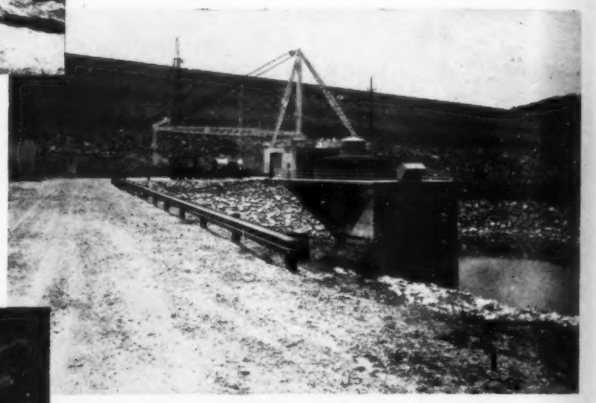
GENERAL ELECTRIC

—U.S.A.—

TVA relies on Leffel Turbines

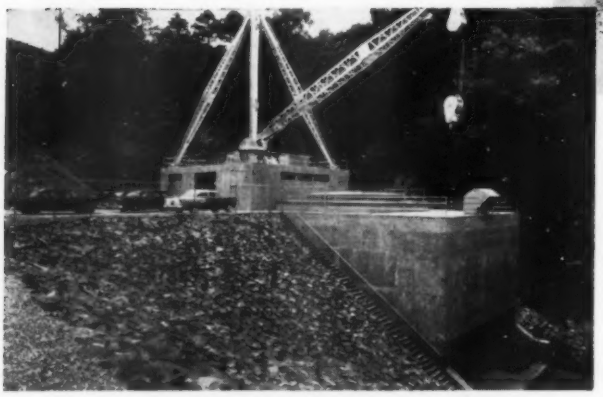
AT WILBUR DAM

In 1950, when the Tennessee Valley Authority decided to expand the capacity of the Wilbur Dam Power station, a Leffel vertical shaft propeller-type turbine was selected. This turbine is rated at 11,500 HP, operating at 180 RPM under a net head of 67 feet.



AT CHATUGE DAM

The Leffel turbine at Chatuge Dam, another TVA installation near Murphy, North Carolina was also installed in 1955. This turbine is rated at 13,000 HP at 180 RPM under a net head of 100 feet.



AT NOTTELY DAM

At TVA's Nottely Dam on the Nottely River near Murphy, North Carolina the generator is driven by a Leffel turbine installed in 1955. This turbine is rated at 21,000 HP, operating at 180 RPM under a 124 foot net head.

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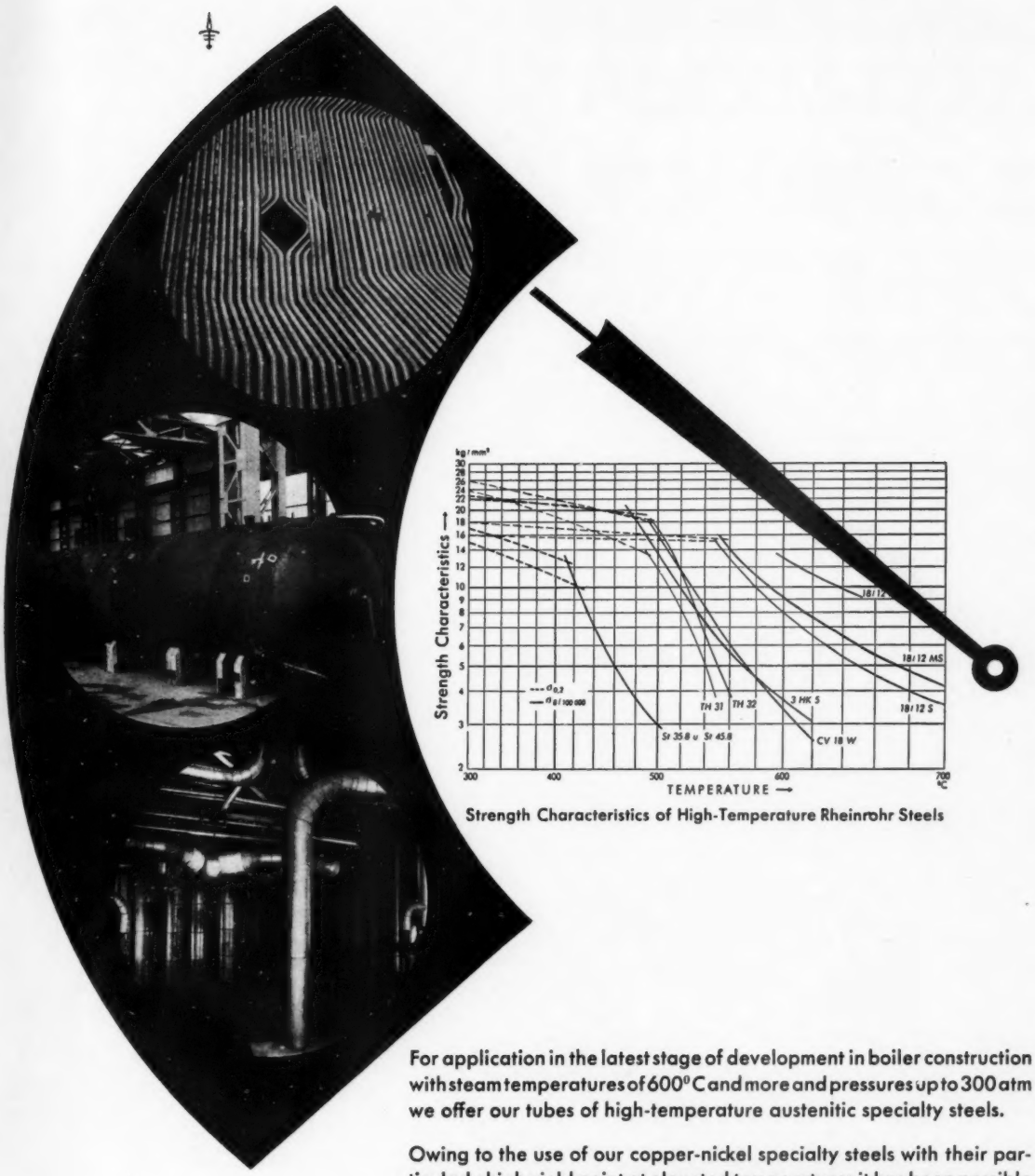

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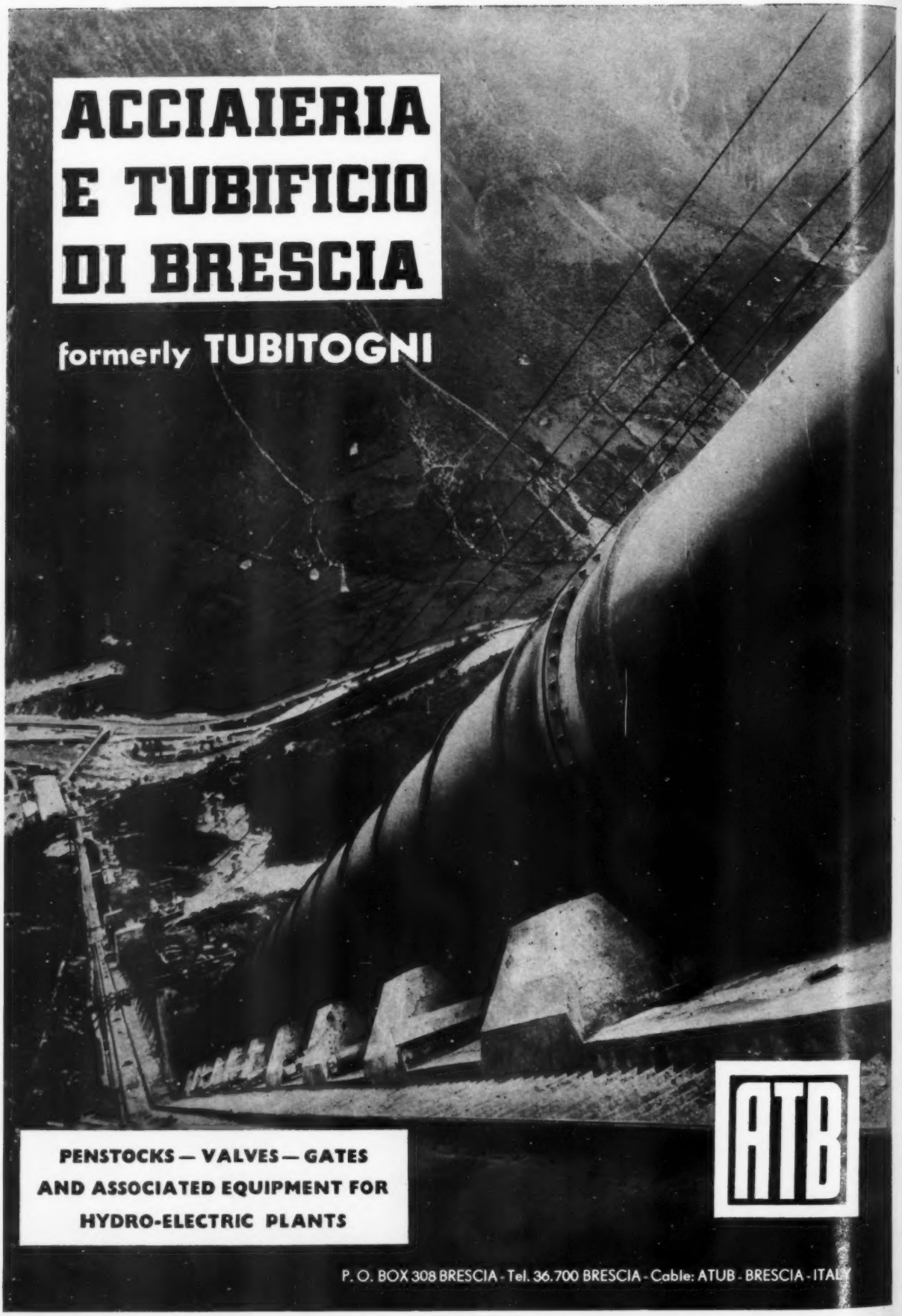

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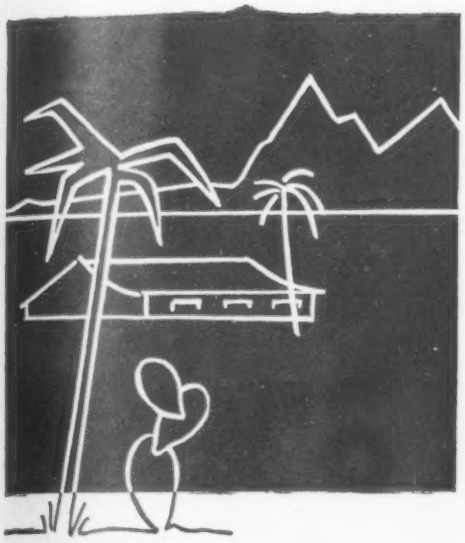

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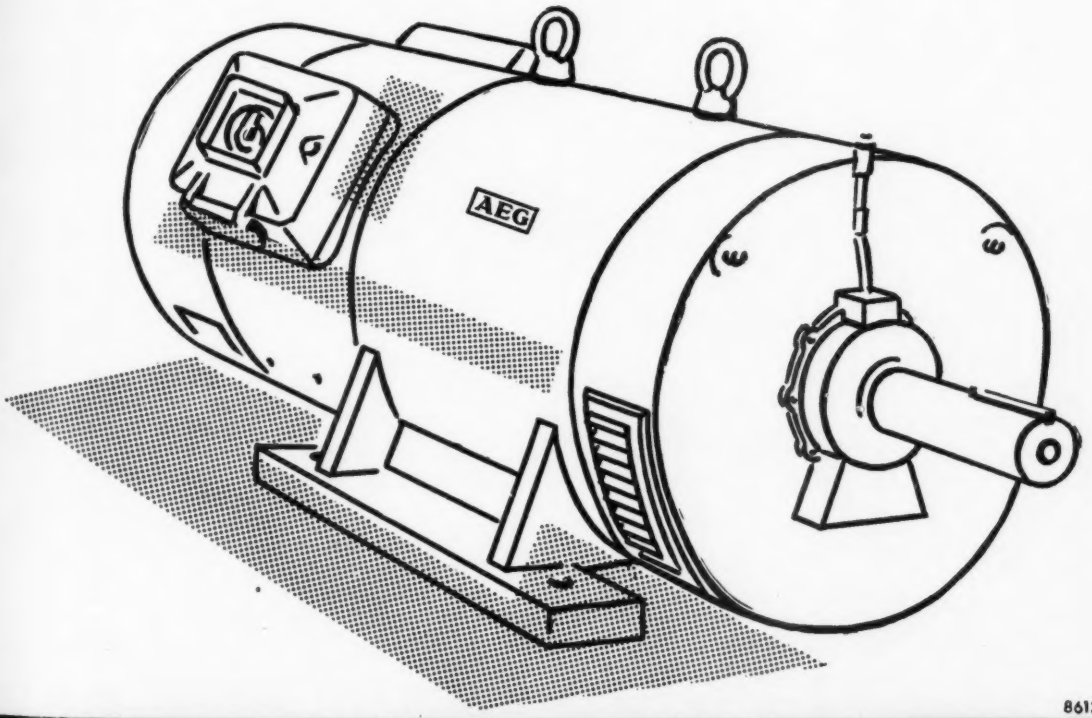

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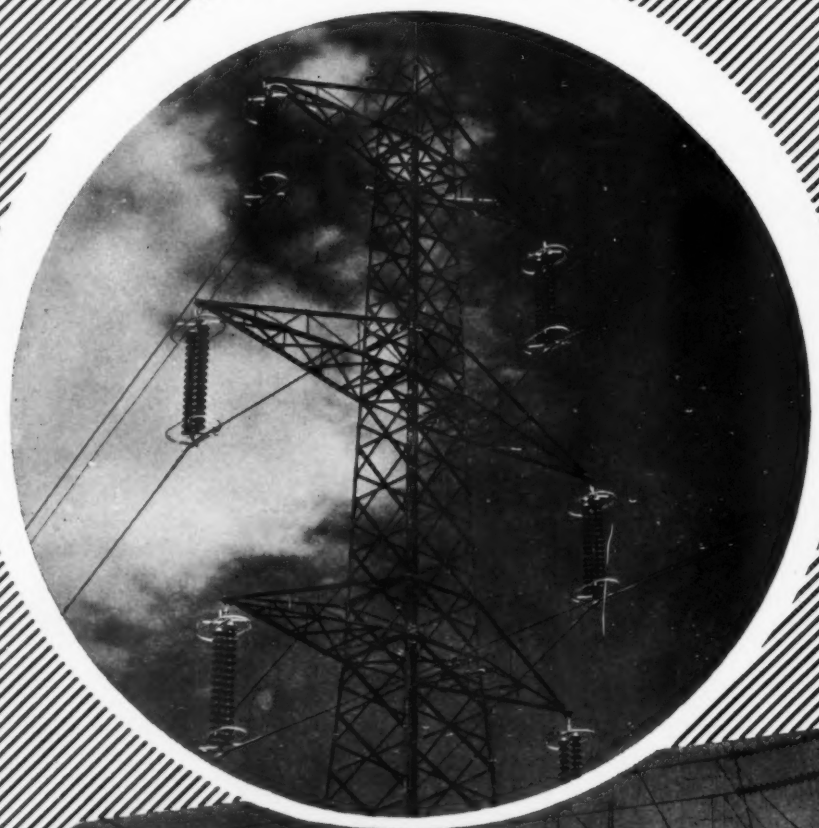

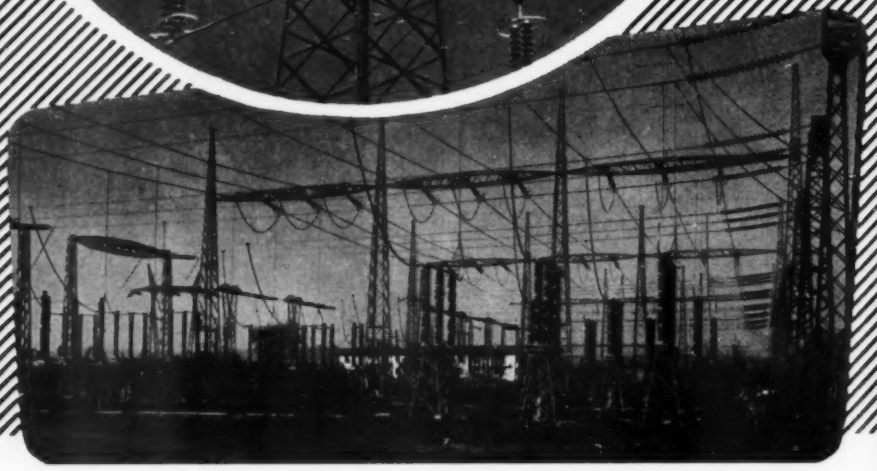

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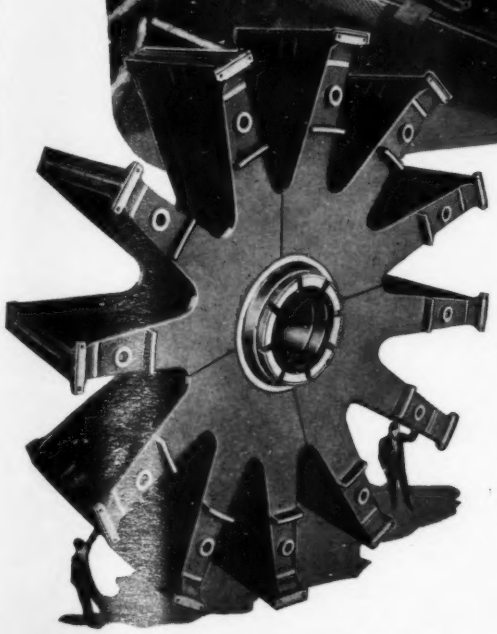
The stator frame of one of the three 150,000 kVA generators for the Stornorrfors Power-station, Sweden. The total weight of the generator is 925 tons.



The rotor spider with a diameter of 8.36 metres and a weight of 86 tons for one of the Stornorrfors generators.

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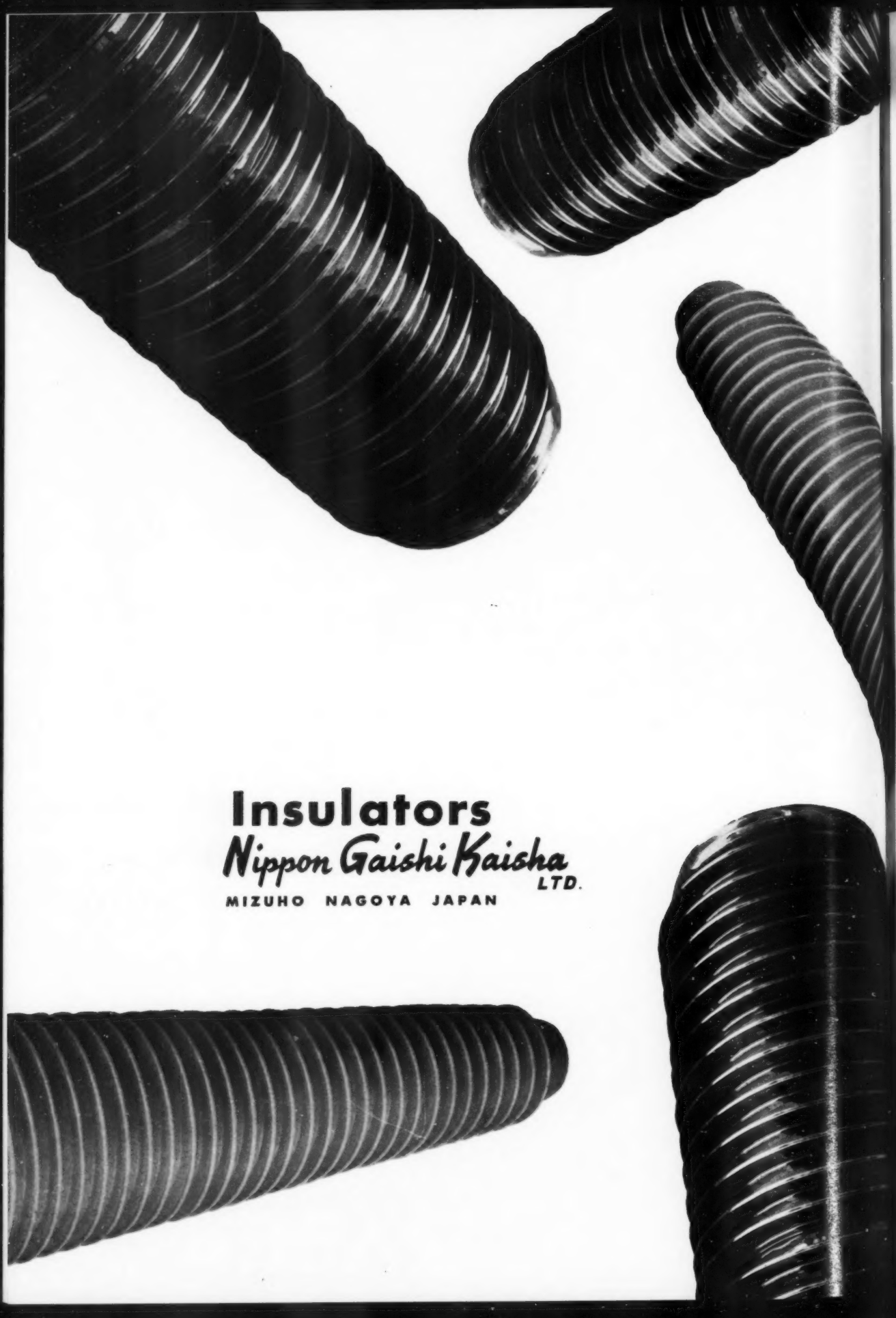
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Volume 11 Number 9

CONTENTS FOR SEPTEMBER, 1959

Editorial: Columbia River Basin Development - - 323

Editorial Notes - - - - - 324

Hydraulics Research Board Report - - - 326

Large-Scale Pumped Storage—II - - - 327

A Tunnelling Symposium - - - - 335
By G. J. Shrimpton, B.Sc., A.C.S.M., A.M.I.M.M., F.G.S.

Fast-Response Static Automatic Voltage Regulators for Hydro-Electric Stations - - - - 338
By D. C. Evans

Design Floods - - - - - 344

The Upper Vinstra Scheme - - - - 349

Book Reviews - - - - - 353

Blasting Water Channels - - - - 356
By Sten Brännfors, A.S.C.E.

Short Articles: Crane Trailer for Spain—Allis-Chalmers Trashrack Rake—German Contracts for Caroni - 358

Abstracts from the World Technical Press - - 360

Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

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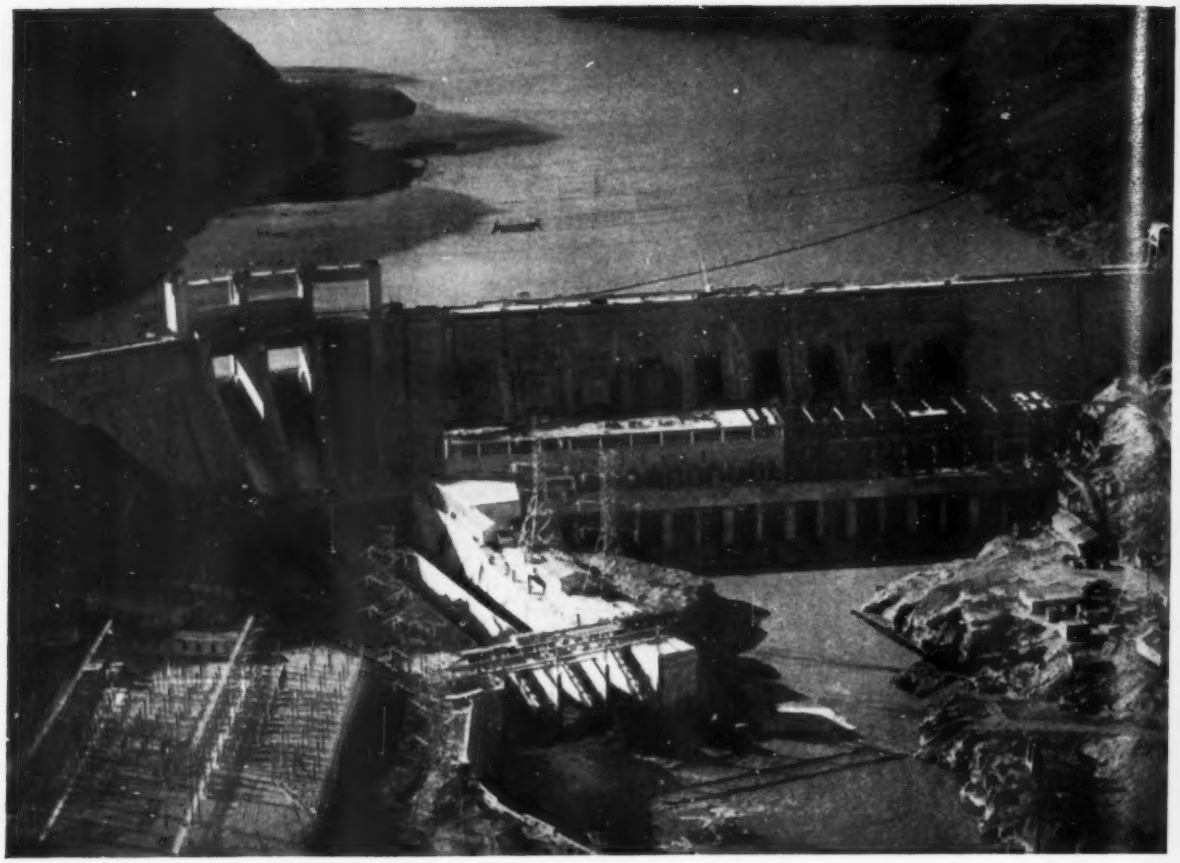

New power for a Dominion from the Roxburgh Hydro-Electric Project

New Zealand's largest hydro-electrical undertaking, the Roxburgh project, will eventually feed an additional 320,000 kilowatts of electricity into the South Island grid system. The 1,200 ft. Dam, which is the largest ever built in the Dominion, was completed far ahead of schedule by Cubitts' New Zealand Co., in association with Conrad Zschokke Ltd., Geneva, and Downer & Co. Ltd., New Zealand.

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A technical journal devoted to the study of all aspects of Hydro-Electric Development

Columbia River Basin Development

AN International Joint Commission was appointed as early as 1944 to consider the water resources of the Columbia river basin and a report* has now been published. The commission was appointed by the Governments of the United States and Canada and was asked to determine whether the further development of the water resources of the basin would be practicable, and to what extent, in regard to power development, land irrigation, navigation, sanitation, flood abatement and the conservation of fish and wild life.

The Columbia river flows both through Canada and the United States and drains an area of 259,000 sq. miles. At the point of maximum length the basin extends north into Canada a distance of 270 miles, the rest of the length, 550 miles, being in the United States. It rises in the Rocky Mountain Trench in British Columbia, this trench being a faulted depression which has subsequently been glaciated to form a U-shaped valley. Towards the west the run-off is characterised by a high winter rainfall from November to the end of February, after which there is a gradual recession until the snow begins to melt. This produces a smaller quantity of run-off compared with the winter rains, but the real recession occurs in late June and continues until September, when the rainy season starts again. In the east, the high run-off period occurs in the spring and early summer and from 70 to 90% of the run-off takes place during the five-month period from April to the end of August. Although the run-off pattern is equalised to some extent by eight lakes having a total area of about 900 sq. miles damaging floods can occur in the lower reaches of the river, and in 1894 and 1948 the flow exceeded a million cusecs, although normal floods are restricted to about 600,000 cusecs. The exceptional floods are, however, devastating as the river can rise 34 ft. above low-water level.

The mountainous nature of the run-off area combines with the ample supply of water to give a large hydro-electric potential. In the United States section this potential is estimated to be 35 million kW of installed capacity giving an annual yield of 170 billion kWh per annum. For Canada, the installed-capacity potential is estimated at 6 million kW, capable of producing 30 billion kWh per annum. Of this potential about 43 billion kWh are being realised in the United States and 2·7 billion kWh in Canada. An immediate programme of expansion in the United States portion of the river envisages a further addition of over 4 million kW of installed capacity but no additional work is at present in hand in Canada.

To make optimum use of the power potential of the upstream storage capacity of the river it would be necessary to prevent excessive floodwater from passing uselessly over the spillways. At present the storage capacity of dams affecting the main river plants does not exceed 13·3 million acre feet, whereas if all practicable dam sites were utilised the report considers that the total storage capacity would need to amount to 50 million acre feet. Such an equalisation of the flow is essential to the full development of the river basin but, in this matter, there are grounds for conflict not only between Canada and the United States but also between conflicting interests in the United States itself. The report argues that virtually all the composite requirements of the situation could be met by a planned co-operative use of the total storage facilities and that this would require the operation of individual plants to be modified to meet both the total load requirements of the basin itself together with the adjacent consuming areas, whereas at present the generating plant is naturally adjusted to suit local loads. Moreover, the relatively small amount of steam power supplied to the basin is said to be rather expensive as it is not provided by plants of modern design. However, the problem of co-ordinating water power and other forms of power will always exist and it is recognised that much study will have to be devoted to keeping a proper balance between varying systems of generation. An important part of the scheme which

* "Water Resources of the Columbia River Basin." Prepared by the International Columbia River Engineering Board. 1959 International Joint Commission, Ottawa, Ontario, and Washington, D.C.

scarcely concerns WATER POWER is that its execution would lead to the irrigation of 5 million acres of unproductive land by 1960 and to nearly 9 million acres by 2010. Other matters refer to stream pollution (mainly the result of sewage from large cities), fish and other wild life, and the provision of locks to facilitate transport. It is concluded, however, that the largest and most valuable benefit to be obtained from the development of the water resources of the Columbia river basin is the production of hydro-electric power and that the further development of these resources is of prime importance, so far as the public interest is concerned and, therefore, to the Governments of both Canada and the United States. It is stressed in the report that the orderly development of the Columbia basin presupposes that the most economical projects should be constructed first and that this desirable process cannot be followed completely in existing circumstances, nor, indeed, until co-operative development is made possible by previous international agreement. An important point in the Commission's report is that a substantial measure of flood control could be obtained in the lower part of the basin without any significant loss of power generation, but this objective would be greatly furthered by the construction of storage projects on the upper Columbia and Kootenay rivers, especially if they were to be operated under international agreement. It is merely fair to say that in British Columbia there are no major flooding problems and that any additional power generated would have to be transmitted to the west coast, especially to the Vancouver area, before it could find a market. The projects considered in the report cover the salient features of any major plan of co-ordinated development which may be contemplated by responsible bodies in Canada and the United States, but it is stated that no physical obstacles lie in the way of agreement nor need there be any unsolvable problems between the two countries.

Megdova Project, Greece

BY the courtesy of Société Commerciale Technique et Industrielle (COTECI) we are able to give some corrected particulars of the hydro-electric development on the Megdova river, Greece, which they are constructing in collaboration with Omnium Lyonnais, and which was referred to in an Editorial Note in our April issue. A reservoir capacity of about 250 million cu. m. will be made available by a dam 73.3 m. high. Three 40 MW units are to be installed, operating under a net head of 534 m. In addition to producing power, the development will irrigate an area of 114 sq. km.

Sectional Meeting, World Power Conference, 1960

A SECTIONAL meeting of the World Power Conference is to be held in Madrid from June 5-9, 1960. The theme of this Conference will be: Methods for solving Power Shortage Problems. Arrangements have been made by the Papers Committee (chairman: Sir Josiah Eccles, CBE) for the preparation of 17 or 18 papers, for presentation by the British National Committee at this Sectional Meeting of the World Power Conference.

The general programme, containing membership and other application forms, together with particulars of six alternative post-conference tours, is announced for publication by the Spanish National Committee towards the end of November 1959. Copies will be distributed as soon as they have reached the British National Committee. In the meantime preliminary notifications of intention to participate should be sent to: The Secretary, British National Committee, World Power Conference, 201-2 Grand Buildings, Trafalgar Square, London, W.C.2. Such notifications will not commit those by whom they are made.

At the Annual General Meeting of the British National Committee held on May 20, 1959, Sir Christopher Hinton, KBE, FRS (chairman, Central Electricity Generating Board) was unanimously elected vice-chairman of the British National Committee in succession to Sir John Hacking.

Bhakra Dam Failure

THE Bhakra dam across the Sutlej River, which is part of the great Bhakra-Nangal project in India, has suffered a major setback. A structural failure in the intake hoist chamber caused water from the diversion tunnel to sweep away the control tower, enter the gallery system and the body of the dam, and flood the left power plant.

It is reported that 10 lives were lost, and the estimated damage was put at over half a crore of rupees (£375,000 approximately). The plant was so badly damaged that the power production programme is now delayed by at least six months.

Ybbs-Persenbeug in Full Activity

THE last of the three 45,000 kVA generating sets of the Ybbs-Persenbeug North power house was put on the line in June. The full-capacity trials of the plant, described at length in our issue of June 1956, proved thoroughly successful, and all the tests carried out were highly satisfactory. The Oesterreichische Donaukraftwerke A.G. can justly be proud of this achievement which adds a maximum capacity of 200,000 kW to the Austrian grid system, and an average yearly production of 1,274 GWh. The commissioning of the last of the Ybbs-Persenbeug generating sets enabled the plant to reach its highest daily production figure so far recorded, namely, 4,486,000 kWh.

American Specialists Visit Russia

HARRY A. KULJIAN, president of The Kuljian Corporation, engineers and constructors, of Philadelphia, and Harvey F. McPhail, manager of the Hydroelectric Division, have been appointed non-paid consultants to the team from the Senate Committee on Interior and Insular Affairs which has recently visited Russia to view Soviet hydro-electric installations and other power facilities. The appointments were made by Senator James E. Murray of Montana, chairman of the Senate Committee.

Harry Kuljian has designed and engineered more than 80 power plants throughout the world. Harvey McPhail, former Assistant Commissioner of the U.S. Bureau of Reclamation for Irrigation and Power, has played a major role in the design and supervision of some of the world's largest power projects, including the Grand Coulee, Hoover and Shasta Dams.

Other members of the Senate team were Senator

Frank E. Moss of Utah, acting chairman; Senator Ernest Gruening of Alaska; Vic Reinemer, executive secretary to Senator Murray; Michael W. Straus, former U.S. Commissioner of Reclamation; Milton C. Mapes, of the Committee Staff; Clyde Ellis, general manager, National Rural Electric Co-operative Association, and Alex Radin, general manager of the American Public Power Association. The nine-man team left for Russia in September.

Water Turbines in a Rubber Plantation

INCREASED power demands at a large rubber plantation in Liberia will be met with the fourth installation of a 1,625 h.p. Allis-Chalmers hydraulic turbine and associated electrical generating and distributing equipment. The plantation is owned by the Firestone Tire & Rubber Company whose principal Liberian headquarters are in Harbel.

The equipment will be similar to the three existing units and will include generator, switchgear and power transformer, in addition to the turbine. Units 1 and 2 were shipped in the early 1940s and No. 3 in 1952.

All four turbines, of the vertical Francis type, are rated 1,625 h.p., 360 r.p.m., and operate under 65 ft. of head. Other equipment to be furnished by Allis-Chalmers includes a 1,250 kVA synchronous generator with direct-connected exciter; metalclad switchgear for generator control; and 1,250 kVA, 3 phase, 60 cycle, 13.2-2.4 kV power transformer.

Upper Namsen Scheme, Norway

THE World Bank has approved a loan, equivalent to $20 million, to Norway for the further development of electric power facilities. The loan will help to finance the construction of two power plants having a combined capacity of 168 MW. These will be situated on the Upper Namsen river, which will be diverted through a number of natural lakes which will serve as reservoirs and provide almost complete annual regulation of the flow of water without the necessity for large and costly civil works. The two hydro-electric stations will be the Tunnsjø plant, having a capacity of 23 MW, and the Tunnsjødal plant, having a capacity of 145 MW. Half the power from the plants will supply the region served by the grid centred around the Trondheim area, and the remainder will be exported to Sweden.

The loan will also be used for the construction of 350 miles of transmission lines to reinforce the power grids in middle and southern Norway and to connect the Aura and Oslo systems for the first time.

Construction of the power plants and transmission lines is scheduled for completion by the end of 1963 at a total cost estimated at the equivalent of $54 million.

Bank Loan for Brazil

THE World Bank has made a loan of $11.6 million to the Brazilian Traction Light & Power Co. Ltd. to help finance projects which will add 220 MW of generating capacity to the systems serving Rio de Janeiro, São Paulo and Santos. Three of the four installations being financed are for the São Paulo electric power system. They consist of the installation of two generating units with a combined capacity of 130 MW in the Cubatão hydro-electric power station, increasing capacity at this plant to 390 MW; the installation of an additional pump to increase the flow of water to the Cubatão station; and the construction of a new section of the high-voltage transmission system which brings power to the city of São Paulo. Water for the Cubatão stations goes through a pumping system from the River Tiete into the Billings reservoir south of the city of São Paulo.

The fourth installation is a 90 MW hydro-electric power station serving the Rio de Janeiro power system. This plant is being built at Ponte Coberta on the Lajes river and will utilise the discharge from two existing power stations situated upstream. One of them, the Nilo Pecanha, was built with the assistance of Bank funds.

Benmore Progress

IN our March 1958 issue we were able to announce that operations had been begun on the Benmore site in South Island, New Zealand. At that time the equipment in use was modestly confined to a mechanical shovel which was working on the shores of the Waitaki river, but the equipment now includes stationary plant capable of producing 4,000 cu. ft. of compressed air per min., an electric supply, emergency power provided by diesel engines and a concrete plant —this last having been transferred from the completed operations at Roxburgh. Downstream of the site a new bridge is under construction to give better transport facilities. The major component of the project will consist of an earth dam 360 ft. high and having a total crest length of 2,000 ft., and containing about 16 million cu. yd. of rock and earth. Excavation of the diversion culverts is expected to be completed shortly and will involve the removal of some 450,000 cu. yd. of material. The project is expected to cost about £36,400,000 and to have a capacity of 480,000 kW. It is expected that power will be available in 1965.

Japanese Hydro-Electric Expansion

SINCE 1950 there has been a remarkable increase in the amount of hydro-electric machinery manufactured in Japan. In that year hydraulic generators were being turned out at the rate of 162,570 kW capacity per annum whereas in 1958 the total capacity manufactured was no less than 1,132,900 kW. There has been a similar increase in the manufacture of power transformers which has risen from 1 million kVA capacity in 1950 to nearly 10 million kVA in 1958. Of the electrical equipment in general the weight of exports has been quite small and has amounted to rather less than 3% of the whole, and is thus a very much smaller proportion than that exported before the war. In the period under review hydraulic power plant has been sent to Formosa, India, Mexico and Ecuador.

In building dams in Japan particular attention has to be given to making structures that are able to withstand earthquake shocks. Intensive attention has been directed to seismological studies and the results of these studies have naturally been applied to the design of dams. No particular type of dam has proved superior to any other, and all types—gravity, buttress, arch, hollow and rock and earthfill—are represented in Japanese hydro-electric practice.

Hydraulics Research Board Report

IN their annual report for 1958 which has just been published,* the Hydraulics Research Station at Wallingford have described interesting scale-model studies in connection with four hydro-electric schemes, three of which are projects in Greece, Venezuela and Malaya, the fourth being a model investigation in connection with the proposed pumped-storage scheme at Blaenau Ffestiniog in North Wales.

Model tests have been completed on the Kakavakia dam which is to be situated on the River Megdova in southern Greece. This dam will be of a thin-arch construction 80 m. high at the centre and 220 m. long at its crest and will have an unusual feature. The basin receiving the flow will mainly consist of a central trench into which the valves discharge and a raised concrete shelf on each side of the gorge to take the flow from the spillways. On each side of the central trench, divide walls 30 m. long will prevent water from the spillways impinging on the valves.

The tests were to determine the width and profile of the spillways, and the form of the piers and guides to allow an estimated flow of 250 cu. m. per sec. to pass without exceeding the maximum design level. The form of the receiving basin was also investigated.

A model was constructed to a scale of 1 in. : 1 m. (1/39·4) and from the tests carried out it was recommended that the spillway width be increased by 25% and the piers be shortened. The jets from the valves were found to discharge freely except at maximum flows when some water from the spillways mounted the divide and fell on the jets. This was overcome by the addition of a second pair of guide walls. It was also observed that a small widening of the gorge downstream would be advantageous as the more gradual constriction of the flow lessened erosion.

Investigations were carried out on the Macagua No. 1 spillweir to compare the performance of different structures for the overflow section of a dam on the River Caroni in Venezuela and which would cope with maximum floods of 40,000 cu. m. per sec. (1,400,000 cusecs). The types investigated initially were: (i) a twin-arch structure, and (ii) a closed-Ambursen type. Geometrically similar models were constructed, scale 1 in. : 1 m. and tested according to the Froude Law and the weirs were calibrated. It was found that a twin-arch spillweir could be 12% shorter than the closed-Ambursen spillweir at maximum flood level, but the flow characteristics of the latter were more satisfactory at all stages with even distribution of flow across the 2,080 m. long spillweir.

Scour tests were then made and showed the closed-Ambursen spillweir to be more favourable especially with a crenellated bucket exit. During all the experiments it was attempted to keep the tailwater conditions critical.

Further tests were done on the closed-Ambursen spillweir at reduced bed levels to compare the performance of the bucket-type structure under drowned and free-jet conditions, and showed an increase in scour in the latter. But this occurred well downstream, thus not affecting the foundations.

An investigation of the Telom weir in Malaya, briefly described in WATER POWER, October 1958, p. 396, was carried out by the Hydraulics Research Station for the Cameron Highlands hydro-electric scheme. The weir is to be sited on a bend across the River Telom and is to divert the normal flow of about 300 cusecs over a side-weir into a drop-shaft. This flow will be augmented by the tributary river Kial which will join the Telom upstream of the weir. Since the position of outflow from this tributary affects the manner in which the sediment is carried into the weir area, a model of 1 : 30 scale, geometrically similar, was constructed and the experiments were devoted to this aspect. It was found that as the point of outflow from the Kial is brought nearer the weir, the sediment is carried over the weir but the inclination of the channel exit had to be increased to control scouring. This would then require some stilling arrangement at the entry and this extra constructional work would not be justifiable.

In a study of the stability of the bed material deposited under normal discharges, it was found to be necessary to arrange for regular scouring of the accumulated deposits by means of scour gates.

The intake chamber was also investigated and tests showed there would be substantially less entrainment if the drop-shaft were sited off-centre with a small guide wall to give rotary motion to the descending flow.

The lower reservoir of the pumped-storage scheme at Blaenau Ffestiniog provided the next investigation. Surplus electricity during off-peak demands will be used to pump water from the lower reservoir into lake Hwlan, the upper reservoir, and returned via generating sets during peak periods. But in emergencies such as power failure to the pumps, water from the pipelines would discharge directly into the reservoir. This might cause undesirable surges and a 1 : 60 scale model of the lower reservoir was built, together with pumps and valves controlled by cams to stimulate the actions in any sequence. The periods of oscillation in the reservoir during the tests were timed and surges measured. Simultaneous discharging of the valves produced a surge of 1 ft. 6 in. height (prototype) near the power station but this was harmlessly dissipated over the lake area. In the test of sudden stoppage of pumps, an oscillation of 3 in. (prototype) amplitude was recorded.

Flow conditions at pump intakes were also considered. Due to the position of the power station and shape of reservoir, vortices were formed which increased in intensity as the lake level fell. Experiments were conducted to eliminate these vortices which could cause air to be entrained at the pump intakes. A satisfactory scheme was evolved for all conditions which consisted of a guide wall combined with a forebay with both north and south walls splayed.

A further interesting analysis was made to determine the relationship between rainfall on the catchment of a river and the resultant flow. At first, an extensive study of available literature was made whereby a theoretical basis was formed. Then a pilot study was made on the catchment of Canons Brook at Harlow New Town and the investigations are still proceeding.

* "Hydraulics Research, 1958." Department of Scientific and Industrial Research. Published by H.M.S.O. Price 5s. 6d.

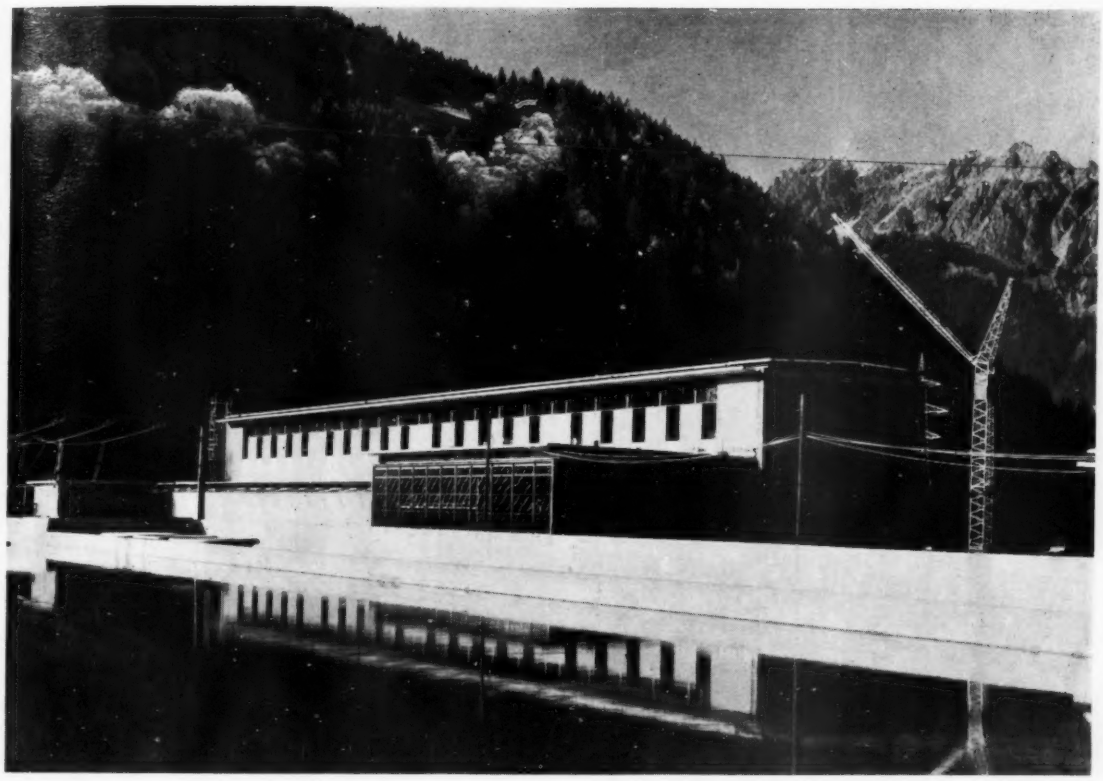


Fig. 10. Lünersee station seen from across the pumping basin

Large-Scale Pumped Storage

The Vorarlberger Illwerke system in western Austria has been designed primarily to supply peak-load power to the Central European Grid. At Lünersee the organisation possesses what is believed to be the largest pumped-storage station in the world yet in operation

PART TWO

LUNERSEE station on the bank of Latschau reservoir, is a particularly interesting piece of engineering design. As already mentioned, it is one of the largest pumped-storage stations in the world, and its hydraulic layout and the design of the main pumping/generating sets are both unusual.

A layout drawing of the station is given in Fig. 12, but the general arrangement can best be considered in conjunction with that of the main units, a sectional elevation of one of which appears in Fig. 11. The station is designed to accommodate six 56 MVA main units, and five have already been installed.

The high head available from Lünersee lake (977·5 m.) made Pelton turbines the only possible choice, but the introduction of storage pumps led to the adoption of a vertical-shaft arrangement as the pumps had to be set very low to avoid cavitation under a maximum surge of 16 m. Even so, it was not feasible to arrange for the pumps to draw directly from Latschau reservoir, as the turbines obviously had to be set above maximum water level in the reservoir (992·25 m.), and to have set the pumps low enough to have drawn satisfactorily from minimum water level (981·5 m.) would have resulted in impossibly long machines. A pumping basin has therefore been constructed on the mountainside behind the station in which the water stands at a level of 1,002·9 m.

This pumping basin can be seen in the general view of the station, Fig. 10, but its arrangement is best followed from the station plan, Fig. 12. The free-flow headwater conduit from Vermunt station discharges to a forebay from which five sluice gates admit water direct to the pumping basin. The small Latschau power plant, which utilises the head between the head-

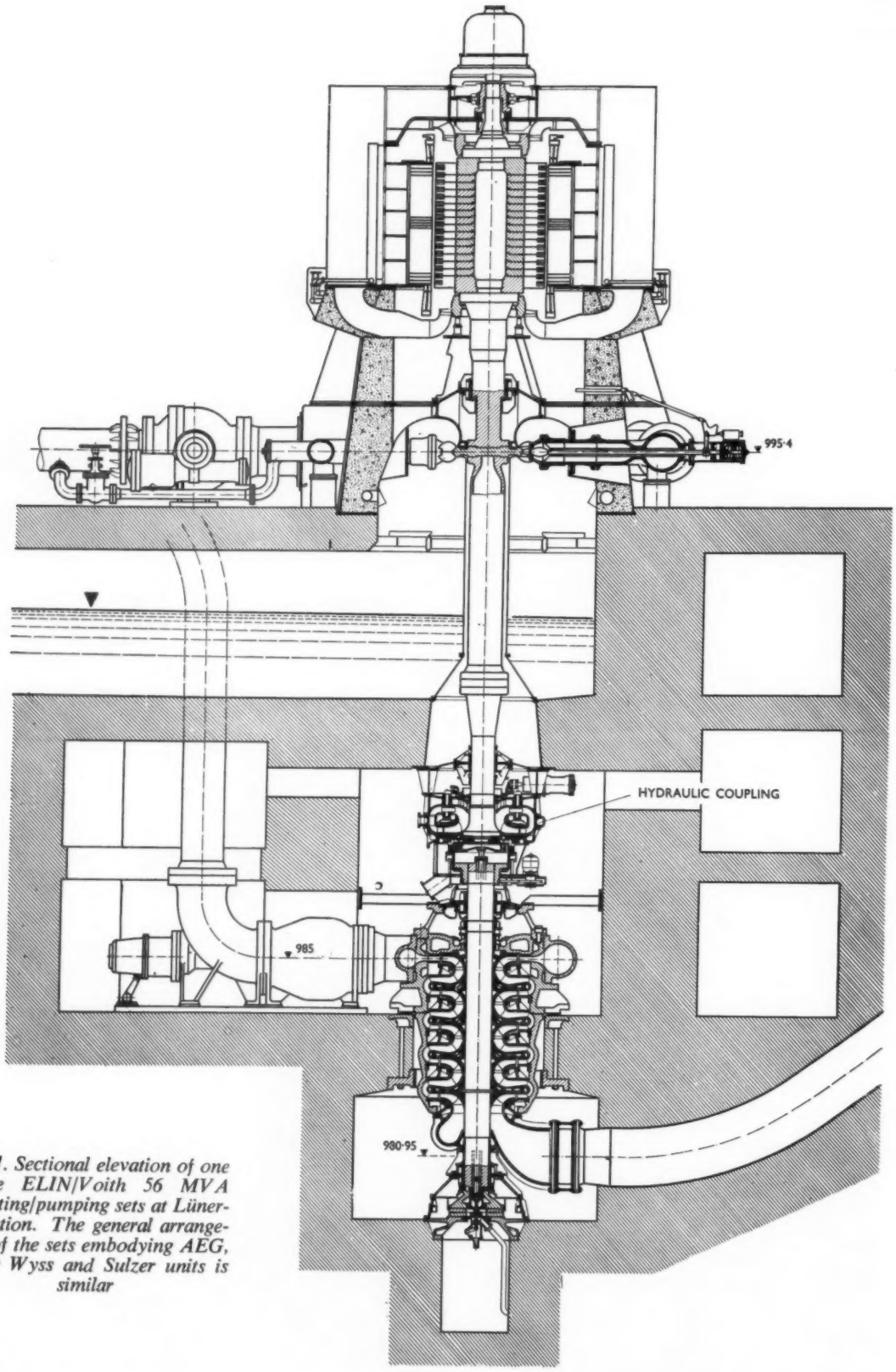


Fig. 11. Sectional elevation of one of the ELIN/Voith 56 MVA generating/pumping sets at Lünersee station. The general arrangement of the sets embodying AEG, Escher Wyss and Sulzer units is similar

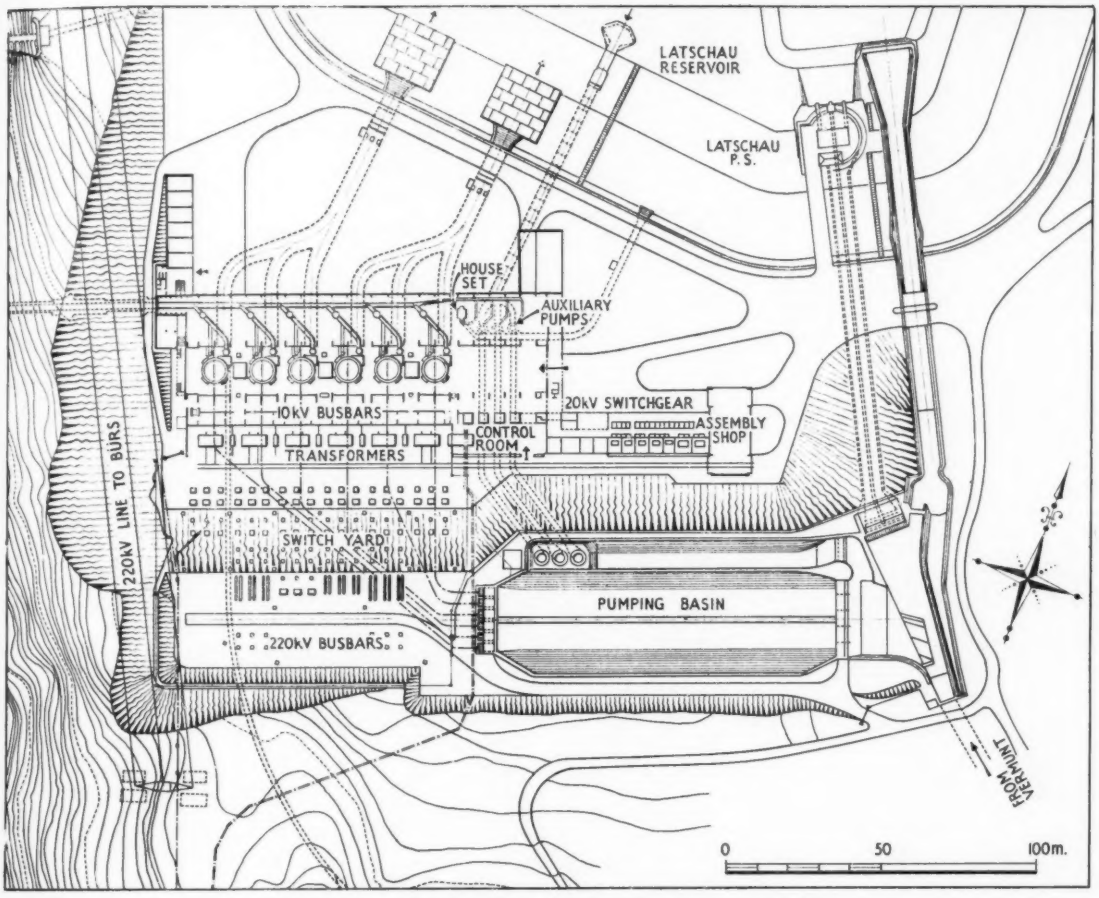


Fig. 12. Layout plan of Lünersee pumped-storage station

water conduit and Latschau reservoir, is also served from this forebay, and any excess floodwater from the headwater conduit passes over an overflow sill forming the right flank of the forebay and enters a channel discharging into Latschau reservoir. Incidentally it will now be clear why a low-head power station at Latschau was called for.

The head sluices for the six main pumps are arranged at the end of the pumping basin opposite to the sluices leading from the forebay.

Should the flow from the headwater conduit be insufficient to meet the demand of the pumps, it becomes necessary to supplement it with water from Latschau reservoir, and for this purpose three low-lift pumps are installed in Lünersee station. They discharge into the channel alongside the pumping basin and thence over the sill into the basin. The hydraulic connections of the main and auxiliary pumps can be followed in the station plan, Fig. 12.

Referring, now, to the sectional elevation through one of the main generating/pumping sets, Fig. 11, each machine comprises four main units arranged vertically in line. At the top is the generator/motor, surmounted by its exciter, the shaft being carried in an upper combined thrust and guide bearing and a lower guide bearing. Bolted to the bottom flange of this shaft is the Pelton runner, and below the runner a hollow extension shaft passes down through a cylindrical fairing in the tailrace chamber to a hydraulic torque converter, the upper bearing of which acts as the bottom bearing of the extension shaft. The driven half of this torque converter is coupled to the shaft of a five-stage centrifugal pump, which has upper and lower guide bearings and a footstep bearing. The servomotor for the torque converter is located below the footstep bearing. The total height of the set is 30 m., and it runs at 750 r.p.m.

From the view in the machine hall, Fig. 13, it will be seen that the main floor is just below turbine level. A concrete cradle carried on four massive columns supports the generator, and the turbine nozzles pass through the spaces between the concrete columns, the turbine chamber being enclosed in a sheet-metal casing.

The electrical machines for the first two units were built by AEG and for the remaining three machines by ELIN. A view of one of the rotors, taken in the ELIN works, is reproduced in Fig. 16. It is of the plate type with cast-steel poles and carries a damper winding. The stator is split to facilitate transport and is arranged for closed-circuit ventilation. Each machine is rated at 56 MVA as a generator and 54 MVA as a motor, the power factor in the two conditions being 0·8 and 0·9 respectively.

The turbines for the first two machines were built by J. M. Voith, Heidenheim, and for the remaining sets by Escher Wyss, Ravensburg. They are four-nozzle machines, each developing 62,800 h.p. under a net head of 972 m. and discharging 5·525 cu. m. per sec. at full load.

The torque converters, all of which were supplied by J. M. Voith, Heidenheim, are believed to be the largest couplings of this type ever to have been built. They were required to meet the very special operating conditions of the Illwerke system, which call for frequent and rapid changes from power generation to pumping and vice versa. The method in use at Rodund of emptying the pump by compressed air, running it up to speed by a small auxiliary Pelton wheel, and engaging a mechanical coupling was not considered feasible owing to the greatly increased size of the sets and the much greater head to be overcome. With the torque converter the pump is started full, with the delivery valve closed, and the changeover from full generation to full pumping, or vice versa, can be effected in 80 sec.

One of these torque converters in course of assembly in the maker's works can be seen in Fig. 17 and a completely assembled unit is depicted in Fig. 18. An impeller is bolted to the end of the turbine shaft and is encircled by a runner bolted to the pump shaft. In the outer part of the annulus forming the hydraulic circuit is a set of fixed guide vanes, and in the upper part is a set of movable vanes controlled by servomotors. To start the pump, water is introduced from the pump intake into this circuit and the movable vanes are opened, enabling the pump to run up to just over synchronous speed. Mechanical connection is then made by a dog clutch consisting of an externally toothed ring on the turbine shaft encircled by a large internally toothed ring on the pump shaft. To engage the clutch a mating ring, toothed both internally and externally, is slid up between the other two rings by means of a servomotor located below the pump and operating through the hollow pump shaft.

Fig. 14, taken in the station basement, shows the torque converter and pump for one of the main sets. The pumps for the first two machines were built by J. M. Voith, Heidenheim (who therefore supplied all the hydraulic equipment for these two sets); for the third and fourth machines the pumps were supplied by Escher Wyss, Ravensburg, and for the fifth machine by Gebr. Sulzer, Winterthur.

Most of the special steel castings for the turbines and pumps were supplied by George Fischer Limited, Schaffhausen. They include the runners for all the turbines and all the torque converters, the impellers for the Escher Wyss pumps and the casings for the Escher Wyss and Sulzer pumps.

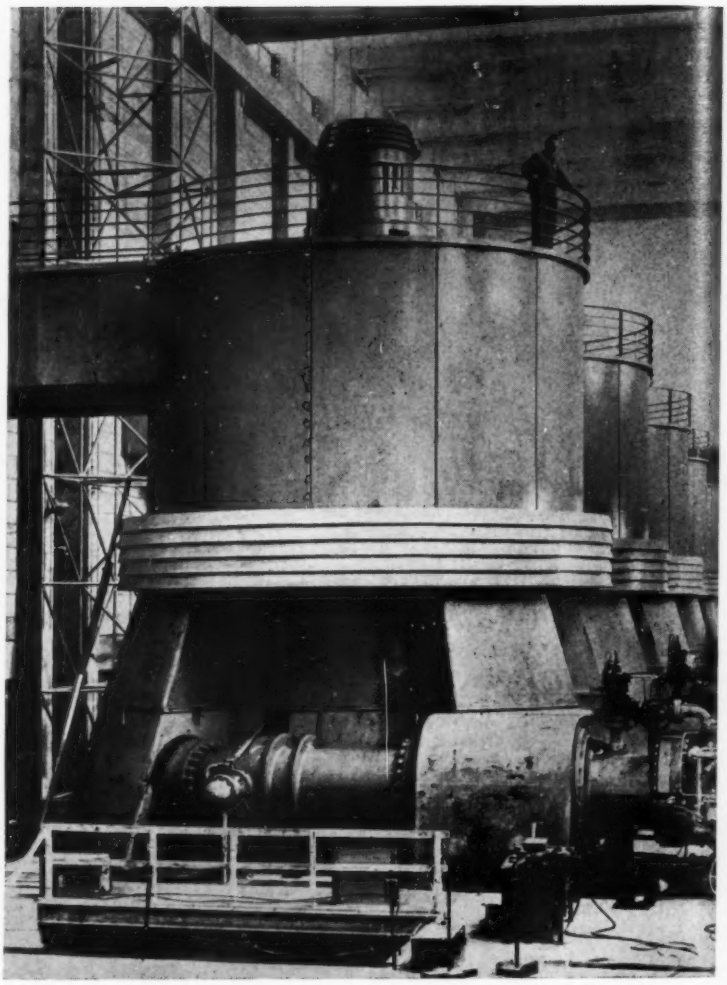


Fig. 13. The five 56 MVA sets seen from the turbine floor

The delivery head against which these pumps operate (an actual difference in level of 968 m.) is probably the highest for which pumps of this size have so far been constructed. At this head each pump is rated to deliver 3·73 cu. m. per sec. when absorbing 55,500 h.p. at 750 r.p.m., but is designed to run, if necessary, at 780 r.p.m. corresponding to a frequency of 52 c.p.s., the power required then being 66,400 h.p. All the pumps are designed as five-stage single-entry units, and the casings have withstood a test pressure of 115 atm. for the lower casing and 190 atm. for the upper casing.

The auxiliary pumps for transferring water from Latschau reservoir are vertical-shaft units each consisting of a Maschinenfabrik Andritz Pelton wheel coupled to an Andritz pump through a Renk, Augsburg, 4·5 : 1 reduction gear. Each is rated to make deliveries ranging from 8·4 cu. m. per sec. against a head of 13·3 m. to 4·2 cu. m. per sec. against a head

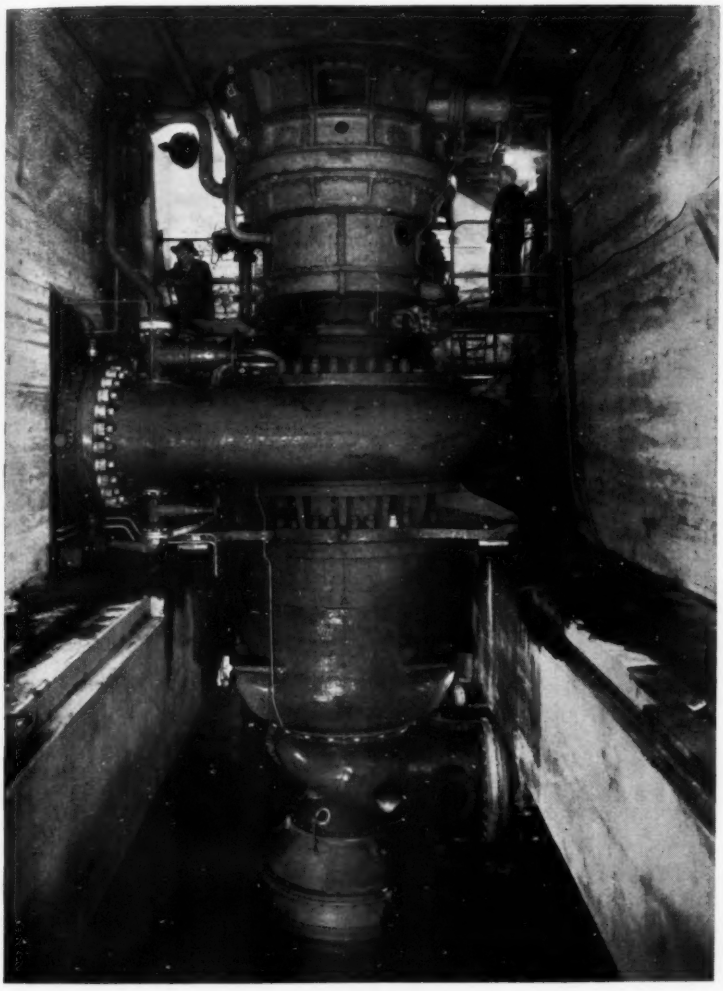


Fig. 14. One of the storage pumps with its hydraulic torque converter

of 24·5 m., and is also designed to run at a speed corresponding to 52 c.p.s.

Auxiliary Services

In the annexe containing the pumps just mentioned a house-service set is also installed, consisting of an Andritz horizontal Pelton turbine driving a 2,200 kVA 400/231 V ELIN alternator. This supplies a 380/220 V essential-services board, and to safeguard these services a standby supply is brought up from Rodund by cable at 20 kV to a double-busbar board which is connected to the essential-services board through two 1,250 kVA Elektrobau, Linz, transformers.

Non-essential services are fed from a separate 380/220 V board which can be supplied either from the house generator or through two additional 1,250 kVA EBG transformers from a separate 20 kV overhead line from Rodund. This line is connected to a separate section of the 20 kV double-busbar board mentioned above, but the two sections can be connected by a bus coupled switch to enable either the cable or the overhead line to feed both auxiliary boards.

Main Electrical System

Each of the main electrical machines is connected to a 56 MVA 10·5/240 kV transformer, the transformers for the first two sets having being built by Siemens Schuckertwerke and those for the three remaining sets by ELIN. One of the ELIN transformers is depicted in Fig. 20. The neutral point of each transformer is brought out on the high-voltage side, and any fault to earth trips the main circuit breaker. External water coolers are employed, and heat exchangers enable the waste heat to be used for building heating when required.

The outdoor switchyard is arranged on two levels, behind the station, the transformers and circuit breakers, which are of the air-operated type supplied by AEG, Kassel, being on the lower level and the isolators and busbars on the higher level. A double-circuit 220 kV transmission line leads down to the main Illwerke substation at Bürs.

The load-despatching centre at Rodund is fully equipped with telemeters, telecommunications and signalling, and is connected to the German customers by a carrier-current telephone system. A central frequency regulator at Rodund can be connected to the Rodund, Vermunt or Lünersee stations, and acts directly on the turbine governors through high-frequency carrier-current circuits.

The Bürs substation, which handles the entire power of the system, receives not only the 220 kV line from Lünersee but also two 110 kV double-circuit lines which convey the power from all the Upper Ill stations except Lünersee. The connection between 110 kV and 220 kV is effected by five AEG and Siemens Schuckertwerke transformers of a total capacity of 460 MVA.

The German consumers are supplied by a 220 kV double-circuit line, installed in 1930, strung with a hollow copper cable of 400 sq. mm. section and a steel-reinforced aluminium cable (745 sq. mm. aluminium and 257 sq. mm. steel). In August 1957 an additional double-circuit line was brought into service leading to Dellmensingen near Ulm. It has two-bundle conductors (ACSR of 257/60 sq. mm. nominal cross section) and operates at 220 kV, but is designed so that it can be converted to four-bundle conductors operating at 380 kV.

The Land Vorarlberg is supplied from the 110 kV busbars at Bürs either through a 15 MVA and a 16 MVA ELIN transformer feeding a 50 kV line to a substation at Bludenz, or from a 110 kV double-circuit line (ACSR conductors 150/25 sq. mm.) lead-

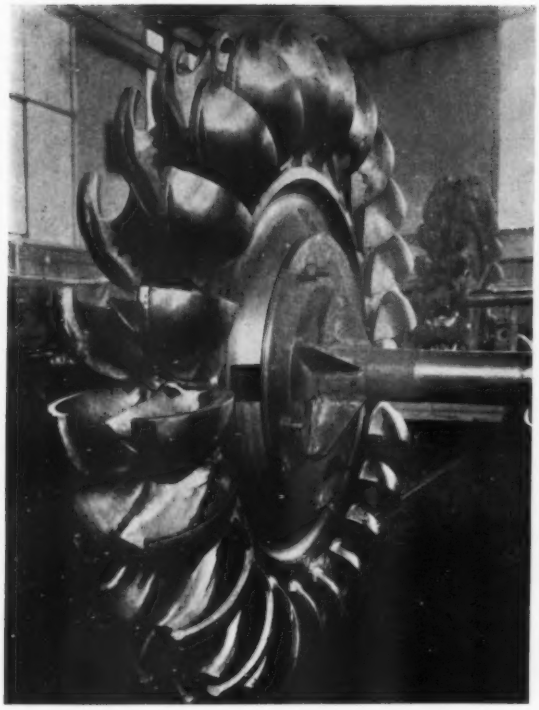


Fig. 15. Fischer Pelton runner for one of the Voith turbines

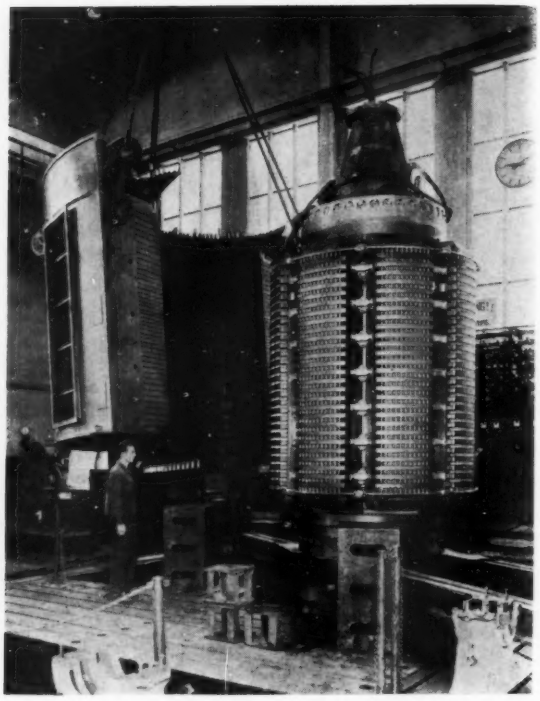


Fig. 16. One of the ELIN motor/alternators in course of assembly

ing to a substation at Rieden near Bregenz.

The Land Tirol and the Verbundgesellschaft are supplied at 110 kV from the Arlberg transmission line operating in parallel with the Rhineland transmission line. This line has been laid out for a double circuit but at present carries only one circuit (ACSR conductors 241/56·5 sq. mm.).

Pumped-Storage Energy Balance

We have already explained that the primary function of the Vorarlberger Illwerke system is to furnish peak-load energy, mainly for industrial purposes. The supply of power to the Austrian authorities mentioned at the beginning of this article is subsidiary, and the planning of the scheme has been conceived essentially in terms of meeting the demands of the German network. To this end constant touch is maintained by telephone between the Illwerke control centre at Rodund and the German control centre at Brauweiler near Köln. The German network is supplied mainly

TABLE II.—ENERGY BALANCE FOR UPPER-ILL/LUNERSEE SYSTEM

Generation	Summer	Winter	Total
	GWh	GWh	GWh
Natural run-of-river output	833	139	972
Effect of seasonal storage on system output	−168	+168	—
Effect on Rodund of seasonal pumped storage at Lünersee ...	−44	+44	—
Output from seasonal pumped storage at Lünersee	—	118	118
Output from daily pumped storage at Lünersee	80	121	201
Output from daily pumped storage at Rodund	—	40	40
Total output	701	630	1331
Consumption			
Power absorbed in seasonal pumping at Lünersee	198	—	198
Power absorbed in daily pumping at Lünersee	135	203	338
Power absorbed in daily pumping at Rodund	—	64	64
Total consumption	333	267	600

Note: All figures are net average annual values as measured at Bürs substation.

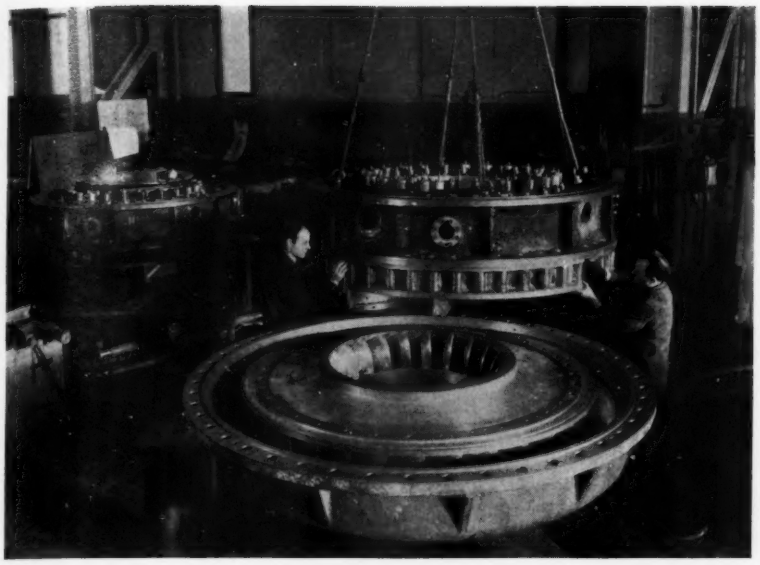
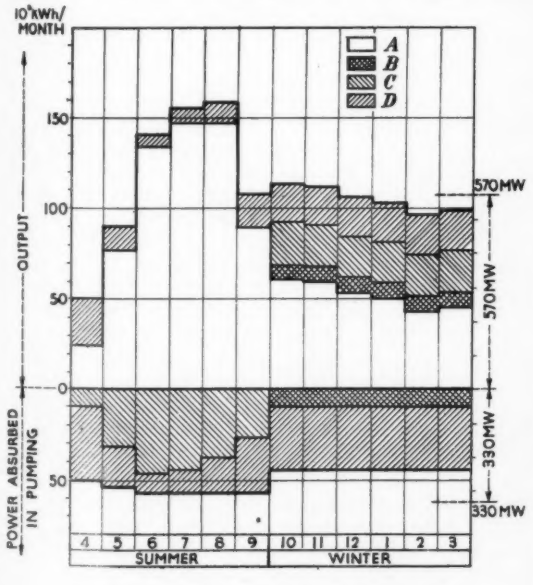


Fig. 17. A Voith torque converter in course of assembly

by steam stations fired by brown coal, and these operate on base load. During factory working hours the peak load is carried by the Illwerke system, but during lunch breaks, nights and week-ends the surplus power from the German steam stations is used to drive the Illwerke storage pumps. The desirability of utilising the surplus power during even the lunch break is the reason why the machines were designed for such rapid changeover from generating to pumping and vice versa; actually it is worthwhile to resort to pumping for as short a period as half an hour.

The construction of the Lünersee station, of course, has greatly enhanced the capacity of the system for this type of service. Previously the only pumped-storage element in the system was the 40 MW pump at Rodund, and the average annual net generating capacity of the system was 347 MW, giving a capacity range for frequency regulation of 387 MW. When the sixth machine has been installed at Lünersee and the second pump at Rodund this station will represent 217 MW of generating capacity and 253 MW of pumping capacity—both average annual net values—so that the Illwerke system will have a total generating capacity of 564 MW and a pumping capacity of 333 MW, representing a capacity range of practically 900 MW.

Lünersee reservoir, as already stated, has a live storage capacity of 76 million cu. m., of which 17 million cu. m. per annum is derived from natural flow and the remainder from pumping. This represents 209 GWh, 152 GWh of which is generated at Lünersee and 57 GWh at Rodund.



A Power generated by the Upper Ill system.
B Effect of Rodund daily pumping.
C Effect of Lünersee seasonal pumping.
D Effect of Lünersee daily pumping.

Fig. 18. Pumped-storage energy balance for the Upper-Ill/Lünersee system

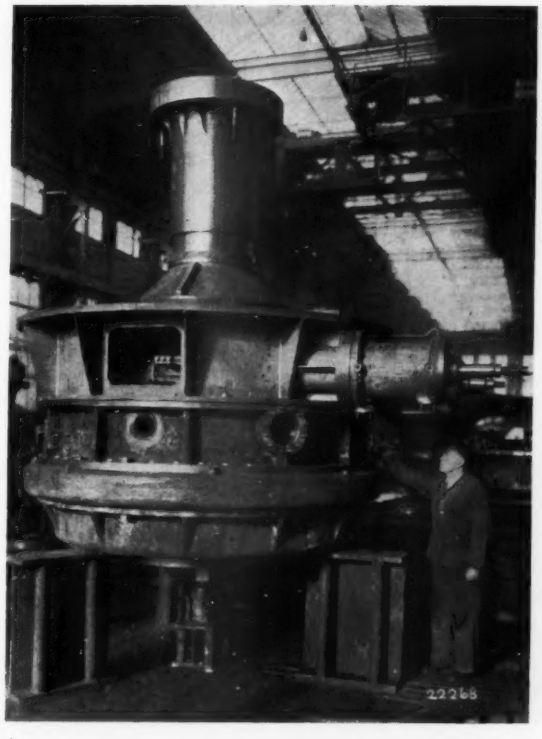


Fig. 19. A completely assembled torque converter in the Voith works

A noteworthy feature of the layout is its flexibility, for the water pumped up to Lünersee from the Upper Ill is used subsequently in the Rodund section, and water pumped up from Rodund can, if desired, be raised through the second stage to Lünersee. Furthermore, Lünersee provides not only peak-load storage but also seasonal storage, enabling surplus summer energy to be stored to provide high-value winter peak energy. Thus the reservoir is subjected simultaneously to two cycles: there is an annual filling and emptying, the highest storage being reached towards the end of the summer; and superimposed on this is a series of fluctuations corresponding to daily, week-end and holiday operating changes. Seasonal storage, of course, is effected entirely by the Lünersee pumps, and these machines are also used throughout the year for short-term pondage. During the winter the Rodund pumps will also assist with daily pondage, but obviously they will not serve for seasonal storage.

Fig. 18 is a diagram of the annual energy pattern as envisaged when the remaining pumps have been

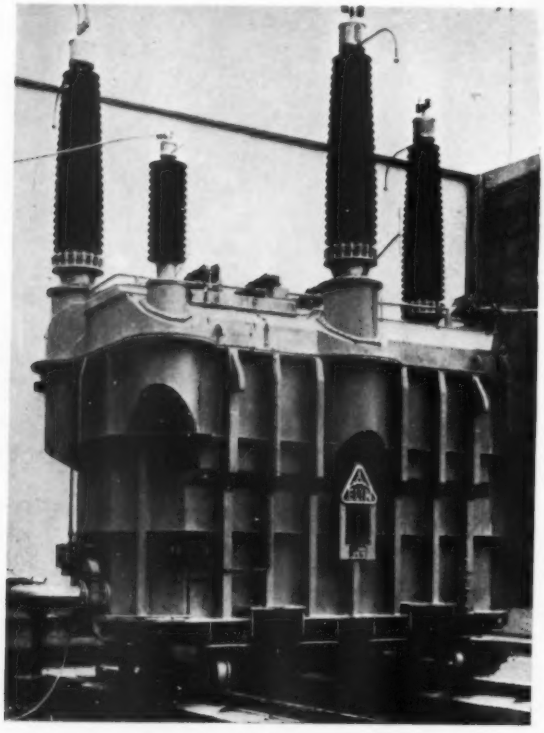


Fig. 20. ELIN 60 MVA 240/10·5 kV three-phase transformer at Lünersee

installed, and the annual energy balance is reduced to figures in Table II. It will be seen that the Illwerke network, when completed, will be capable of a net average annual capacity of over 730 GWh of high-value peak energy.

Finance

During the life of the Vorarlberger Illwerke a number of loans have been raised from outside sources. A mortgage loan of £2 million sterling was borrowed in 1929, and from 1938 to 1944 German loans to the

Fig. 21. Part of the 220/380 kV line from Bürs to the German frontier

extent of Sch. 125 million were raised. A mortgage loan of Sch. 100 million was floated in 1955, but the Lünersee development has been made possible largely by the assistance of the International Bank for Reconstruction and Development, which advanced $10 million in 1955 and DM. 15 million in 1957.

Acknowledgments

We are happy to acknowledge the kindness of Dipl.Ing.Dr.techn.h.c. Anton Ammann, General Director of Vorarlberger Illwerke A.G., in affording us the opportunity to see the various stations and structures in the Illwerke system and to publish this article, and we would particularly thank Dr. Ammann and his colleagues for their courtesy and helpfulness during our visit. Our tour of inspection was organised by the Österreichische Elektrizitätswirtschafts A.G., and we are especially indebted to Dr. Rudolf Stahl the General Director, Herr Albert Wietz the Secretary, and Dr. Erwin Denk for their many good offices.

High-Strength Insulators. A publication issued by Doulton Industrial Porcelains Limited gives details of a particularly tough disc insulator they supply for overhead lines.

Allis-Chalmers. This firm has published a booklet in coloured strip cartoons titled "Better Tomorrows Begin Today at Allis-Chalmers." The booklet is forcible in its appeal and effectively emphasises the fact that Allis-Chalmers makes more products for more industries than any other company in the world.

A Tunnelling Symposium

A summary is given of certain papers presented at a symposium arranged by the Institution of Mining Engineers in London

By G. J. SHRIMPTON, B.Sc., A.C.S.M., A.M.I.M.M., F.G.S.

A THREE-DAY symposium on tunnelling and shaft sinking was held recently in London under the auspices of the Institution of Mining Engineers. Twenty-five papers, contributed by many countries, were presented and discussed, and may be conveniently grouped under three main headings: Tunnelling; Shaft Sinking; Special Subjects. Most of the papers were concerned purely with coal or mineral mining, but a few on tunnelling were of direct interest to engineers engaged in hydro-electric development and will here be summarised.

Tunnelling in Canada

According to M. A. Twidale and A. Ignatieff, who presented a paper on this subject, the great range of conditions encountered in Canada makes it impossible to give a comprehensive survey of Canadian tunnelling practice, but three projects involving widely different conditions will be described. The first of these concerns the Princess Colliery tunnel in Nova Scotia. It is driven at an inclination of 11° through structurally weak and water-bearing strata. The cross section is 18 ft. × 13 ft. high × 3,445 ft. long. A wedge-cut round was used employing 40% Forcite explosive averaging 4·62 lb. per cu. yd. for a 6 ft. pull. A No. 8 B.U. Joy loader was used. Owing to difficulties the Joy loader was replaced by a 48 in. Ingersoll-Rand scraper and millisecond delay detonators were used. An 8 ft. round was then pulled giving an explosive consumption of 3·1 lb. per cu. yd. A further development was the benching which gave an improved explosive consumption of 2·68 lb. per cu. yd. Temporary support was supplied by rock bolts with H-section arch girders as permanent support, set in a concrete lining 18 in. thick. The completed tunnel has a single track and a conveyor belt.

The Kemano hydro-electric tunnel in British Columbia was located in difficult terrain and had to be driven through igneous rock. A strict time limit was given, viz., 3½ years. Road access was not possible, and so a 20 ton capacity aerial tramway was used for all transportation. The western headings of the main tunnel use a three-deck jumbo with twelve 3½ in. Ingersoll-Rand rock drills. The Tahtsa Lake heading employed 21 airleg drills with chisel tungsten-carbide ⅞ in. integral steel The larger holes were charged with 1¼ in. × 8 in. 40% "Giant" gelatin and 1 in. × 8 in. 40% Forcite explosives in the smaller ones. Electrical detonation with ½ sec. delay detonators was used. For ventilation a 22 in. diameter reversible fan was employed in conjunction with 24 in. ducting. Cleaning out was accomplished by 100 h.p. electrically powered Conway loaders and 6 cu. yd. Granbies; these were changed by a cherry-picker incorporated in the drilling jumbo.

Little support was needed apart from rock bolting, the weaker ground (25% of tunnel) being concreted using steel arches as a temporary support.

The third example is taken from the Geco mine in Ontario. Here a lenticular orebody was to be developed in an inaccessible area to produce 3,300 tons of ore daily. The main crosscuts were 8 ft. × 9 ft. in good ground. Three airleg drills with tungsten-carbide chisel bits were employed for a 36 hole round, uncharged burn-cut holes being reamed out with 2½ in. detachable bits. The explosive was a 70% semi-gelatin dynamite, and the tape fuse with detonators was lit by ignitercord. Model 21 Eimco loaders dumped the rock into 60 cu. ft. Granbies hauled by 3½ ton battery locomotives. Fumes and dust were exhausted by a 3,000 cu. ft. per min. fan. Similar equipment was used in driving a 12 ft. × 9 ft. conveyor opening, the operation maintaining an average of three 8 ft. rounds per day.

General Remarks on Canadian Tunnelling Operations

Drilling. In tunnels of small cross section the hand-held airleg rock drill is mainly used for the short holes required, whereas for trackless mining 3 in. and 3½ in. drilling machines mounted on remote controlled booms are employed.

Blasting. In hard rock the five and nine hole burn cut is used in conjunction with low-velocity explosives. V cuts are used in softer formations, and benching in larger tunnels. The explosives are of four main types, viz., gelatins, gelatinous, semi-gelatinous and ammonia dynamite, and are manufactured in varying strengths and sizes, the standard length being 8 in.

Initiation may be by safety fuse with or without ignitercord, or by electrical detonators of either the long-period delay or millisecond type.

Mucking. In trackless operations the caterpillar-mounted shovel is use with a heavy dump truck and shuttle cars, either diesel or electrically powered. The Emico 21, track mounted, is still used in small headings. Eventually car switching will be eliminated by the use of the scraper-mounted train which remains at the face until all the cars are full.

Roof Support. Rock bolting is widely used and aluminium bolts have been used in corrosive conditions, with a possible extension to all bolting operations. Conventional support is still used in broken or loose ground. Where the rock is affected by exposure to moisture or air, guniting is used. Main openings employ reinforced-concrete linings, but

near blasting operations the concrete is not reinforced. The use of steel or aluminium movable forms is standard practice, the concrete being mixed in a central plant and transported by pipeline.

Ventilation and dust control. Water sprays and curtains are used during blasting operations, the question of exhausting or forcing systems of ventilation being governed by local conditions. The use of diesel units has warranted large quantities of fresh air. Where fogging has occurred, the compressed air to the machines has been preheated by a heat exchanger mounted on the jumbo.

Tunnelling in the United States of America

This paper, by S. Kimball, deals with hard-rock tunnelling only. The tendency is towards full mechanisation owing to the high cost of labour, and this had led to the rejection of the Swedish method using airleg-mounted machines in favour of heavier machines mounted on jumbos. Also the high interest rates on capital requires high-speed tunnelling.

In the early days tunnelling was mainly for canals, then railroads and later for hydro-electric schemes, irrigation and municipal water supply. The Feather River project in California, for instance, will require 585 miles of tunnels and canals.

Drilling. The rail or rubber-tyred jumbo has revolutionised tunnel driving. In addition to its role as a drilling platform, it is also used as a platform for the installation of support, and for the incorporation of a cherry-picker for truck changing. Heavy drifters with detachable tungsten carbide bits and high-tensile steels are employed. The burn cut is universal, and frequently incorporates 4 in. to 8 in. diameter relieving holes.

Explosives. The development of a dynamite with a reduced production of gas and smoke has taken place, together with the employment of millisecond-delay detonators which may be initiated from a mains or an exploder circuit.

Ventilation. Both the forced and exhaust system are in use with axivane fans placed at the required intervals.

Mucking. The largest machine that can operate economically is employed, e.g., electrical or diesel power shovels and Conway and Eimco type loaders of 1½ cu. yd. capacity.

Transportation. Trackless diesel equipment is used in tunnels of large cross section and where the grade is excessive. Rail equipment is used by most contractors, and the changing of trucks is accomplished by the cherry-picker, the grasshopper or the Californian switch, the latter being mainly used for the bypassing and storage of trucks. Both electric and diesel locos are employed, the respiratory hazard from the latter having been eliminated by efficient exhaust scrubbers and improved ventilation.

Drainage. Tunnels are usually developed on the upgrade but where water inflow is excessive it is led to sumps placed at intervals, and then pumped through a discharge line.

Power. Electricity is brought in at high voltage and then transformed as required. Compressors are situated outside the tunnel, and air receivers are situated at frequent intervals in the main line.

Management. The importance of good management with efficient planning, organisation and equipment is stressed, together with proper construction of the portal before tunnelling can commence. Also of vital importance is the accuracy of information supplied by geological studies.

An advance of 25 ft. per week achieved some 60 years ago improved to 25 ft. per day in the 1920s, and to 40-50 ft. per day at the present time. In one instance recently 100 ft. was advanced in one day.

Regarding tunnelling in soft rock, 29 ft. diameter tunnels are now being excavated by a continuous miner which is capable of driving 150 ft. per day.

Australian Experience

In a paper entitled "Some Aspects of Underground Work—Snowy Mountains Scheme," W. L. Gilmour describes some of the work being done in the south east of Australia. Here the Great Dividing Range is at its highest, being mainly over 5,000 ft. and is snow covered for many months of the year. The scheme involves the diversions of the Snowy River by a tunnel connecting with the headwaters of the Murray River, the Eucumbene River and the Tumut River. It will provide the greatest part of 1,818,000 acre-ft. of storage water a year for irrigation and power generation.

The contractors for the scheme are from Australia, the United States and France. The area consists largely of granitic and highly folded metamorphosed sedimentary rocks. Tertiary lavas also occur overlying unconsolidated beds of sand, clay, gravel and lignite. The rocks are faulted and generally well jointed.

T.1. Underground Power Station. The granite is intruded into granite gneiss, both being well jointed. Major faults are not present, but several thin crushed seams occur. As the granite was the better rock the machine hall was located in it. Vehicular access is gained by a tunnel 1,400 ft. long, 19 ft. wide and 21 ft. high, on a downgrade of 12½%.

The machine hall is 305 ft. long, 59 ft. wide and 105 ft. high, and the transformer hall 127 ft. long, 56 ft. wide and 44 ft. high. The sequence of excavation of these two halls was achieved by first driving pilot tunnels and widening the excavation in stages. Temporary steel arched supports were used followed by roof bolting and permanent concrete ribs and abutments. In the narrower transformer hall, rock bolts were the only support needed, placed after the excavation of sections C and D.

Jackhammer and airlegs using integral tungsten-carbide-tipped steel were used except for downholes which were drilled by hand-held jackhammers. Only 0·44 lb. of AN60 explosive per cu. yd. was used in the excavation of the machine hall.

In order to observe the behaviour of the excavation various instruments were used, viz., levelling, sensitive clinometers, Carlson strain meters and Huggenburger deformeters, the latter two being used in the emplacement of the concrete ribs. As the excavation progressed downwards geophones were placed in short holes, but this method did not prove satisfactory.

Weekly observations and the plotting of the results showed that the strain increased in the concrete arch ribs; slight bulging took place on the downstream wall, but was less on the upstream side.

Flat-jack tests were undertaken to evaluate the stresses in the concrete ribs and to understand the instrument observations better. These primary stresses were then used in photo-elastic studies to determine

the stresses around the excavation. The results were considerably higher than anticipated, and appeared to be associated with the valley profile effect. High horizontal stresses probably resulted from tectonic activity. The results are regarded as being qualitative rather than quantitative.

Rock-Bolt Investigation. As little was known of the behaviour of rock bolts in unstratified rock, it was decided to investigate, under controlled conditions, the slot-and-wedge-type bolt which had been specified in the contract. Many bolts of 1 in. diameter and having lengths up to 20 ft., had a mean yield-point value of 40,600 lb. per sq. in. and an ultimate strength of 70,000 lb. per sq. in. Wedges from $\frac{1}{2}$ in. to 1 in. square were tested the drill-hole diameter being between $1\frac{1}{16}$ in. and $1\frac{5}{8}$ in. The results showed that the wedges should be not more than $\frac{5}{8}$ in. less than the drill-hole diameter; bolts should be driven for at least 20 seconds at air pressures greater than 80 lb. per sq. in. As the bolt has a net sectional area of 0·55 sq. in. at the slot and the root of the thread, the bolt had a mean yield point of 22,500 lb., a mean ultimate strength of 38,500 lb., and it was shown that 96% of the bolts carried a proof load of 20,000 lb. with less than $\frac{1}{8}$ in anchorage slip. It was noted that the bolts slipped up to $1\frac{3}{8}$ in. on initial load, therefore a preloading of 350 lb. ft. torque is required before retightening to 200-250 lb. ft., i.e., a yield-point safety factor of 1·7.

Removal of drilling sludge must be 100% to minimise anchorage slip. The longer bolts required more care to install and had a greater elongation for a given load. Little difference was noted between the result of 2,000 and 3,000 impacts. With lubricated threads and washer, and the bolt square on the bearing plate, the torque (lb. ft.) was 0·0166 times the tension (lb.), but these figures would be lower under field conditions.

The behaviour of the rock to rock-bolt support was also investigated. It was found that the rock bolt must be installed immediately after the excavation so as to prevent the joints from opening, thus maintaining the friction between the joint surfaces. Photo-elastic studies, although not conclusive, showed that a zone of uniform compression existed parallel to the free face where the bolt length/spacing was less than 2, and that where this ratio equalled 3 the depth of the zone was $\frac{2}{3}$ the length of the bolt. In addition small-scale models using crushed rock of uniform size were investigated with model rock bolts. Similar but larger-scale models were tested and in this case a load of 7,000 lb. was needed before failure, but when reassembled and using chicken wire between the bolt plates and the rock, the model did not fail at 13,000 lb. but collapsed on removal of the chicken wire. The diaphragm was seen to act in a quasi-elastic manner.

Rock-bolting practice. Split-end wedge bolts, 1 in. in diameter and mostly 10 ft. in length, were used. The bolts were tightened by impact wrench to 300 lb. ft. and then slackened to 250 lb. ft. Owing to the proximity of blasting, bolts within 30 to 40 ft. of the face were often retightened. As a check on the load on the bolt, rubber pads were inserted between two circular bearing plates, and pull-out tests were also used. Downward-sloping holes were filled with a cement grout before the bolt was inserted, and a suitable pattern was adopted to aid the miners when installing the bolts.

T.1. Shafts. Two 14 ft. diameter pressure shafts and one $11\frac{1}{2}$ ft. diameter lift shaft were raised 1,200 ft. in stages. The lower two-thirds of the pressure shafts were lined with steel and backfilled with crushed rock which was subsequently grouted, the remainder being concrete lined. As for the lift shaft, the lower 60 ft. was lined with concrete placed against the rock, the portion above consisting of 5 ft. long precast concrete pipes which were backfilled with $1\frac{1}{2}$ in. crushed rock.

T.1. Tailrace Tunnel. This tunnel, the majority of which was 24 ft. by 24 ft. was advanced full face using jackhammers and airlegs with $1\frac{1}{2}$ cu. yard overhead loaders and rear dump units. Rock bolting, steel sets and concrete were used as support.

Eucumbene-Tumut Tunnel. This tunnel is 13·8 miles long and 24 ft. excavated diameter. A junction shaft some 300 ft. deep was situated between the portals to enable four headings in all to be driven. About 60% of the tunnel is in highly folded metamorphosed sedimentary and volcanic rocks, the remainder being largely in granite. The tunnel was driven at almost 90° to the rock formations, and two major and some minor fault zones were intersected.

Survey. The alignment survey was based on a triangulation network which gave the bearings of the centre line of the tunnel. The portal headings were driven on these bearings, while the other two headings, which were driven on these bearings for 7 miles, were transferred down junction shaft. No correction of the shaft bearings was shown to be necessary after breakthrough. To gain experience for future shaft plumbing surveys five methods were investigated. A summary of the results showed that the differences of the various methods, compared with the true value computed after breakthrough, were:—

(i) Optical plumbing (pentagonal prism method) using two T3 theodolites, one at the top and the other at the bottom of the shaft – 10.0 sec.

(ii) Optical plumbing employing two targets on an auxiliary reference line at the top of the shaft, and a T4 theodolite at the the bottom (mean of three transfers) +6.5 sec.

(iii) Light-wire plumbing employing T3 theodolites (mean of three transfers) – 0.8 sec.

(iv) Heavy-wire plumbing using a theodolite to observe the limits of oscillation of each wire (mean of two transfers) +2.1 sec.

(v) Heavy-wire plumbing as above, but using a small scale set up behind each wire, to obtain the true position of the plumbing plane (mean of two transfers) – 2.2 sec.

The underground alignment survey which was controlled in three stages, and the precise levelling showed the following errors at breakthrough:—

	Alignment	Height	Length
Tumut Pond-Junction Shaft section	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.
Junction shaft-Eucumbene section	2 in.	1/25 in.	$\frac{3}{4}$ in.

Excavation. Three rows of four $3\frac{1}{2}$ in. auto-feed drifters mounted on hydraulic booms attached to a drill jumbo, containing a cherry-picker, were used to drill a six-hole wedge-cut round of 70-95 holes pulling an average round of 10·5 ft. Gelignite AN60 and a specially manufactured low-density explosive (Roxite) were used with $\frac{1}{2}$ sec. detonators which were connected in parallel and fired from 415 V a.c. mains. The

(*Continued on page 343*)

Fast-Response Static Automatic Voltage Regulators for Hydro-Electric Stations

The author describes the design and characteristics of modern fast-response, automatic voltage regulators and explains their operational advantages

By D. C. EVANS

FOR many years generator excitation has been controlled by one of two basic types of electro-mechanical automatic voltage regulator: the vibrating-contact type or the rolling-sector type. These have given good service but it is now common to make use of modern automatic-control techniques to provide a regulator which is completely static, and therefore requires very little maintenance. This type of regulator provides faster, more accurate, control of the generator excitation, with improved stability when operating at leading power factors.

The voltage measuring and comparison circuits are built up from static and robust components, and these control magnetic amplifiers which provide fast response, high amplification and great reliability. The main exciter may be controlled by a large magnetic amplifier or by a rotating amplifier. In either case only the main exciter is directly coupled to the generator; no pilot exciter is required and so the overall height of the set is reduced.

The following additional features are commonly demanded in addition to the basic voltage-regulator function:—

1. Parallel-running compensation.
2. Line-drop compensation.
3. Leading MVAR limit (also known as "minimum excitation limit" or "rotor angle limit").
4. Auto and manual rheostat follow-up.
5. Power-factor control.
6. MVAR control.

A typical regulator of this type can correct normal voltage disturbances within 0·75 sec. and on rejection of full load will arrest the ensuing voltage rise within 0·3 sec. and restore the voltage to the correct value within 1·2 sec.

Electro-mechanical Regulators

The vibrating-contact type of regulator connects a fixed amount of resistance in and out of the field circuit, and the average exciter voltage depends on the on-off ratio of the contacts. This ratio is controlled by the position of a beam which is normally held in balance by a solenoid fed from the generator terminal voltage. Any departure of the generator voltage from the set value causes the beam to move, altering the on-off ratio and hence the exciter voltage so as to restore the correct value of generator voltage.

The rolling-sector type of regulator varies the field-circuit resistance in small steps. The taps on a field rheostat are brought out to a number of contacts arranged to form part of a circle, and a sector of conductive material, the position of which is controlled by the generator voltage, short-circuits some of the steps. Any departure from the correct generator voltage causes the sector to move and adjust the field resistance to correct the change.

Being partly mechanical both of these types suffer from wear and friction and require fairly regular attention. Friction reduces the sensitivity and causes a dead zone of between ½% and 1% within which no control action is obtained. The contacts of the vibrating type require regular attention due to erosion caused by sparking. The rate of response of both types is restricted by the mass of the parts that have to be moved. Even when giving full corrective action they cannot force the main exciter voltage to go negative—in order to restrict generator over-voltage on load rejection—as can a regulator employing magnetic or rotating amplifiers.

Basic Duty

Before a generator is synchronised to the system, or following a load rejection, the duty of the automatic voltage regulator is solely to maintain the correct generator terminal voltage. When the generator is on load the duty of the regulator becomes more complex, although fundamentally it still has to control the generator voltage. The generator is usually tied to a large system through a certain amount of external reactance provided by transformers, transmission lines, etc., and the system voltage is very little influenced by a change of terminal voltage on one generator. If the generator terminal voltage changes then the change is accommodated across the external reactance by a corresponding change of reactive load current. Thus although a dead band of, say, 1% in a regulator does not seem very great it may represent a considerable change of reactive load. Hence an accurate regulator leads to a more tightly controlled system.

If a fault or other disturbance occurs on the power system it is usually over quickly but the sudden shock to the system can cause a generator to lose synchronism. The performance of the regulator has a considerable influence on the system stability, but to be effective it must act very rapidly and powerfully, for it is the performance during the first half-second after the start of the disturbance that matters most.

Line Charging

Under certain conditions the generator may be called upon to supply leading current. This is particularly so in the case of hydro-electric generators, which, in many cases, supply the load centre via a long transmission line which takes a considerable leading charging current. This current may have to be supplied

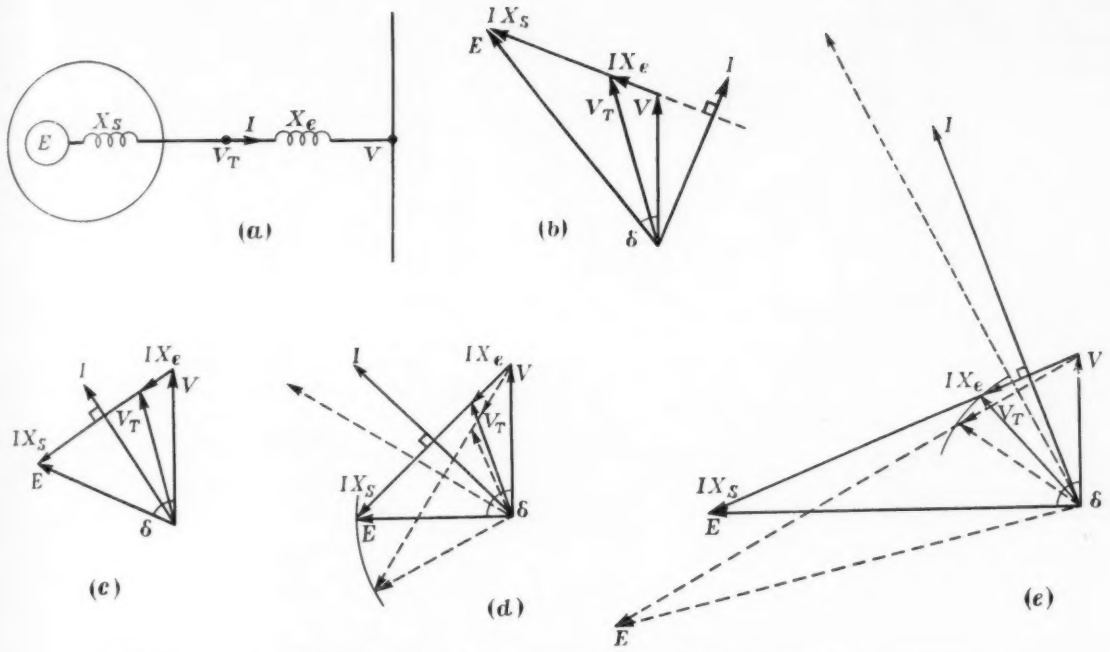


Fig. 1. Diagrams demonstrating the requirements for dynamic stability of a generator

from a small number of generators during periods of low water flow, and so the performance of the generators in the leading region is of some concern. Under manual control of the excitation the leading current that a generator can supply is limited, it being determined mainly by the generator short-circuit ratio and partly by the power-system parameters. If this limit (the manual stability limit) is exceeded the generator loses synchronism with the system. It is common practice in hydro-electric stations to use generators with a high short-circuit ratio, so that a large leading current can be supplied without operating too close to the manual stability limit.

Dynamic Stability

The use of a fast-response regulator allows stable operation of a generator well beyond the manual stability limit. This may be explained with the aid of Fig. 1 which shows at *a* a generator tied to a large system via an external reactance *Xe*. The fictitious generator internal e.m.f. *E*, due to rotor excitation, feeds the machine terminals through the synchronous reactance *Xs*. Fig. 1 *b* is a vector diagram showing conditions when the generator is supplying lagging current. The difference voltages between *V*, *VT*, and *E* are due to the voltage drop in *Xe* and *Xs* respectively. The ratio between the two voltage-drop vectors *IXe* and *IXs* is constant. The current vector *I* is proportional in length to *IXe* and *IXs* and lagging 90° behind them. Fig. 1 *c* is a vector diagram showing conditions when operating well into the leading region.

Under manual excitation control it is assumed that the generator excitation and hence the internal e.m.f. *E*, is constant. It can be shown that the maximum possible power for any fixed value of *E* is generated when the angle δ between *E* and *V* is 90° and this condition is shown in Fig. 1 *d*. The broken lines in this figure show the condition when δ is greater than 90°. It can be seen that although the current I has increased it has swung round more out of phase with V so that the in-phase current, and therefore the generated power, is less than for the 90° condition. The rotor is still being supplied with the same mechanical power by the turbine and so there is a surplus of power which accelerates the rotor still further and synchronism is lost.

The above is true if the rotor excitation is constant, i.e., is under manual control or under control of a comparatively slow regulator. It can be seen in Figs. 1 *b* to *d* that as δ increases *VT* becomes progressively smaller. If a fast-response regulator is used it adjusts the rotor excitation so that *VT* is always held constant, i.e., increases *E* in the diagrams as δ increases. The effect of this is shown in Fig. 1 *e* which should be compared with *d*. *E* has been increased by the regulator so that *VT* is held at the correct value. If δ is increased beyond 90°, as shown by the broken lines, *E* is further increased by the regulator to hold *VT* constant. It can be seen that the in-phase component of current has increased with the increase in δ, showing that the maximum power is no longer limited to that generated when δ is 90°. It is therefore possible to operate the generator with δ greater than 90° without loss of synchronism. The above description is only intended to explain whether or not the generator is likely to lose synchronism during a disturbance when supplying leading current. Obviously under steady conditions the generated power must be equal to that supplied by the turbine, less losses.

As δ increases it becomes more and more difficult for the regulator to boost the excitation fast enough to prevent the rotor pulling out of synchronism. The limit of stability reached when the generator is under control of a fast-response regulator is known as the "dynamic stability limit." Fig. 2 shows a generator performance diagram with typical manual and dynamic

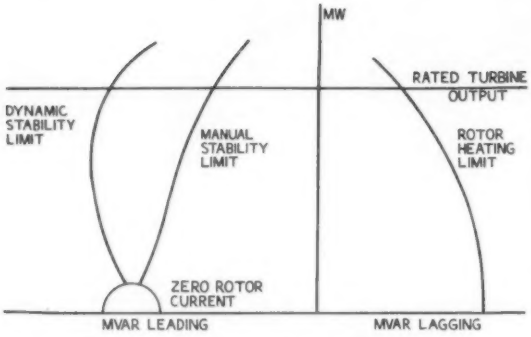


Fig. 2. Generator performance diagram

stability limit lines marked.

The increased capability of the generator in the leading region can be utilised in one of two ways:

1. If a generator with a conventional short-circuit ratio is used a larger leading current can be supplied without risk of losing synchronism with the system.
2. The generator short-circuit ratio can be lower than otherwise advisable, resulting in a cheaper generator.

Main Features of Fast-response Regulators

Modern automatic voltage regulators have three main features, namely high sensitivity, fast response and the use of static components as far as is practicable in order to improve reliability and reduce maintenance. All the measuring and control circuits are electrical to eliminate trouble caused by friction, backlash and wear.

In order to discuss the main components a simple block diagram of the basic regulator is given in Fig. 3. The generator voltage is transformed down to about 110 V and rectified to produce a direct voltage proportional to the generator voltage. This direct voltage is compared with a very stable reference device in a comparison circuit, and if the generator voltage is not of the required value a signal is fed to the first-stage amplifier. The amplified signal then controls the second-stage amplifier, which either bucks or boosts the output of the main exciter so as to bring the generator voltage to the required value. The different parts of this diagram can now be considered in more detail.

Reference Unit

The reference device is required to provide an accurate reference even under extreme conditions of supply voltage, frequency and ambient temperature. One particular specification called for a reference constant within 2% for ±20% supply voltage variation and frequency between 70% and 140% of nominal.

A simple and cheap form of reference is the neon reference tube which maintains a constant voltage over a wide range of current. This type, however, must be replaced occasionally and is not considered to be as rugged as the transformers, magnetic amplifiers, metal rectifiers, etc., composing the rest of the regulator. Of similar application to the neon tube is the recently developed Zener diode. This is a special type of silicon rectifier that maintains a reverse voltage over a wide range of reverse current which is sufficiently constant to be used as a reference. Because of its construction the Zener diode is considered to be far more rugged and reliable than a neon tube.

Reference devices have been made which use as a reference the saturation flux level of a magnetic core. One such circuit uses a combination of linear and saturating reactors, resistors, rectifiers and capacitors to compensate for variation of supply voltage, frequency and ambient temperature, producing a very accurate reference over a wide range of these variables. Another circuit uses a type of constant-voltage transformer to produce an approximate constant supply in conjunction with a Zener-diode-controlled transductor to trim the output over a range of a few per cent. to an accurate constant level.

Amplifying Stages

The requirement of high sensitivity demands the use of at least two stages of power amplification in front of the main exciter. Electronic amplifiers and mercury-arc rectifiers have occasionally been used, but on the ground of reliability the only power amplifiers in general use are the rotating amplifier and the magnetic amplifier.

The first-stage amplifier is almost invariably a magnetic amplifier having an output of perhaps a few hundred watts. It is usually a push-pull amplifier in order to supply buck and boost signals to the second stage, and is adjusted so that if no control signal is present the net output is zero. Occasionally the second stage is biased to give full output in, say, the buck direction and then a single-ended first stage is used having sufficient output to produce full output from the second stage in the boost direction. The first-stage amplifier in this case is adjusted so that if no control signal is present the output is half of maximum and so the second-stage output is zero. This arrangement leads to a small economy but whether or not this justifies the unbalanced form of control is debatable.

The second stage is required to control the main exciter and must have sufficient power to force the main exciter output to respond rapidly. On a large slow-speed generator a peak output of as much as 50 kW may be required, and because of the large amount of power a rotating amplifier is frequently used. Rotating amplifiers having the required output are readily built and have a fairly high gain and fast response. It is, however, becoming more common for

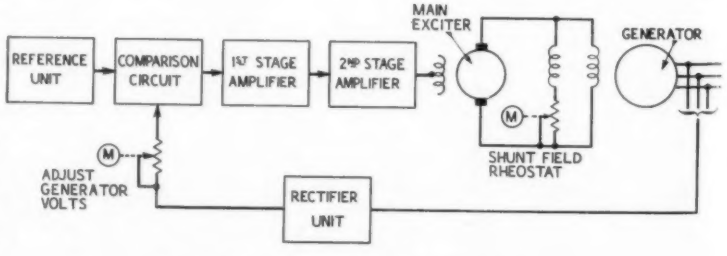


Fig. 3. Block diagram of basic regulator

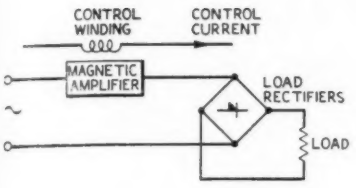


Fig. 4. Basic magnetic amplifier circuit

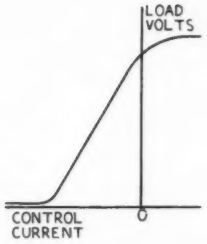


Fig. 5. Typical magnetic-amplifier control curve

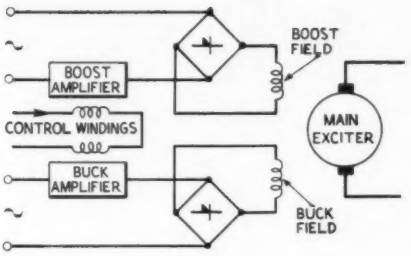


Fig. 6. Circuit for push-pull magnetic amplifiers

magnetic amplifiers to be used for the second stage as well as the first. Push-pull operation is required and because of the large power involved three-phase magnetic amplifiers are used. The performance of the regulator is improved by the use of a magnetic-amplifier second stage, as the gain and speed of response are both higher than they would be for a rotating amplifier. From the reliability point of view it is an obvious advantage to replace a rotating amplifier requiring occasional maintenance of its brushgear and commutator with a static magnetic amplifier requiring no maintenance at all.

Rotating Amplifiers

A rotating amplifier is a special form of exciter, and two basic types can be said to exist: single-stage and two-stage. The single-stage type is a conventional exciter but usually has a laminated frame for fast response. Frequently a shunt or series field is used so that the exciter is largely self-exciting; the control field then only has to supply a small trimming signal, and is much more effective than if it had to supply the whole excitation.

The two-stage type takes several forms but all of them incorporate two exciters into one machine so that a large power amplification is obtained.

Magnetic Amplifiers

Saturable reactors have been used as a variable impedance in a.c. circuits for many years, and the modern magnetic amplifier has been developed from them. Special circuits, core materials and forms of construction are used in order to provide high amplification and fast response.

The amplifier is connected in series with the a.c. supply and the load through a rectifier bridge, as shown in Fig. 4. A magnetic amplifier is best regarded as a device capable of absorbing a certain percentage of the alternating supply voltage, the percentage being varied by the control current fed into the amplifier control windings. That part of the supply voltage not absorbed by the amplifier appears across the load. Thus by varying the amplifier control current the proportion of the supply voltage appearing across the load can be controlled. The type of control characteristic obtained is shown in Fig. 5.

The magnetic amplifier shown in Fig. 4 has a unidirectional output. If bi-directional output is required then two magnetic amplifiers connected in push-pull are used. One method of obtaining push-pull output is shown in Fig. 6. The amplifiers are required to control the main exciter, which has buck and boost windings on each pole. The amplifiers provide excitation in opposite directions and their control windings are connected in opposition so that the control current increases the output of one amplifier and decreases the output of the other. The effective excitation on the exciter depends on the difference in the amplifier outputs.

The most convenient supply frequency to use for powering the amplifiers is that of the power system, as a suitable supply is readily available. However, as with transformers, the physical size of the amplifier for a given rating is reduced as the frequency is increased and a useful saving in space and cost results. Equally as important is the fact that the speed of response increases with the frequency, and so it is common to run the magnetic amplifiers at a frequency of 400 c/s (or 480 c/s on 60 c/s systems). This means that a high-frequency supply is required, and one method is to use a squirrel-cage induction motor driving a permanent-magnet generator. These have been built with rated outputs up to 100 kVA, and as they use a permanently magnetised rotor they have no sliprings and require no excitation supply. The only parts of the high-frequency generator set that need any attention are the bearings. In one respect this system is more reliable than the use of power-system frequency; should the station supply fail momentarily due to a fault, the inertia of the generator will allow it to continue supplying the regulator, which would otherwise be seriously disturbed by the loss of supply.

Main Exciter

The main exciter is of conventional design except when the frame is of laminated construction in order to prevent an increase in response time due to eddy currents. The main exciter is coupled to the generator, but the rotating amplifier and high-frequency generator for magnetic-amplifier supply are driven by a separate motor. In order that manual control of the generator excitation may be always available the main exciter must have a conventional shunt field and rheostat. From the point of view of the regulator this is an advantage, for the main-exciter shunt field supplies most of the excitation required and nearly all of the output of the second-stage amplifier is then available for forcing the main-exciter output to change rapidly. Methods of supplying the main-exciter field from the second-stage amplifier vary. Always with a magnetic-amplifier second stage, and sometimes with a rotating amplifier, the buck or boost signal is fed to additional field windings on the main-exciter poles. Sometimes when a rotating amplifier is used its

armature is put in series with the shunt field and rheostat so that the same field winding is used for shunt excitation and for bucking and boosting.

Parallel-running Compensation

When several generators are tied directly together on a station bus each regulator measures the same voltage, i.e., the common terminal voltage of the paralleled generators. If the voltage settings of the individual regulators are slightly different one or more will boost in an attempt to raise the terminal voltage and the others will buck to achieve the opposite result. The effect of this is to produce a large reactive current circulating between the machines. If the generators were tied to the bus through reactors this difficulty would be very much reduced, the small differences between the regulated voltages of the individual generators and the bus voltage being taken up across the reactors with a reasonably small flow of reactive current.

In practice it would not be desirable to use such reactors, but a similar effect can be obtained by the use of parallel-running compensation or "quadrature droop" as it is sometimes called. This varies the regulated voltage according to the reactive current supplied, the voltage decreasing as the lagging current increases. Hence if the generators are paralleled and

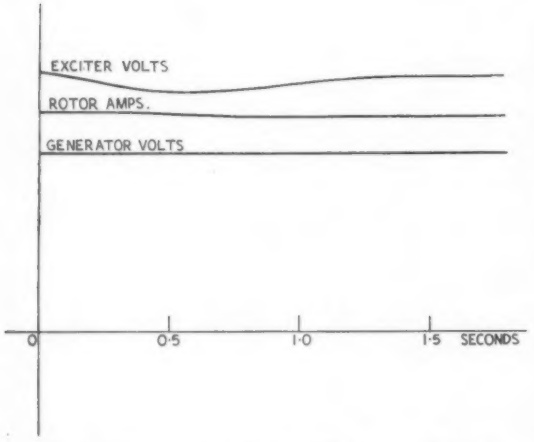


Fig. 7. Response to -1% change of voltage setting

their regulators are set for slightly different voltages a reasonably small interchange of reactive current is sufficient to adjust the regulated voltages to the same value.

Line-drop Compensation

If a station supplies the load centre through a long transmission line there is a considerable voltage drop along the line. It may be considered advisable to control the generated voltage so that the line-voltage drop is compensated for and the load voltage remains constant. Most of the line impedance is reactive and so it is largely the reactive current that causes the load voltage to drop. The line-drop compensation unit therefore increases the generator voltage as the lagging current increases. The circuits used for this are identical to those used for parallel-running compensation except that the current signal is obtained from the total line current and not, as for parallel-running

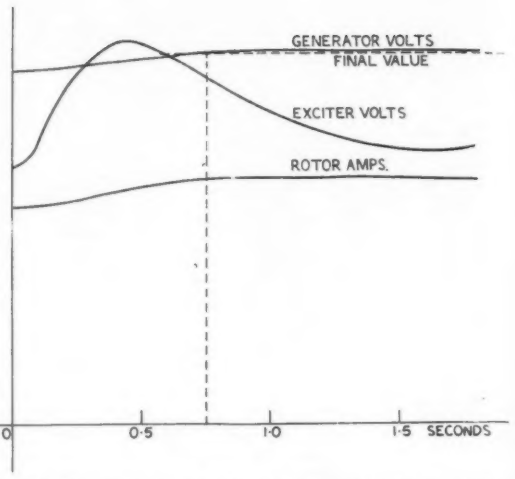


Fig. 8. Response to +4·8% change of voltage setting

compensation, from the current of the individual generator.

Leading MVAR Limit

Although the use of a regulator helps considerably to keep the generator in synchronism during system disturbances, there is obviously a limit to its capabilities. It is therefore becoming common to use a circuit designed to detect when the generator is operating too close to the stability limit, and to take strong corrective action. When the generator is approaching the steady-state stability limit, generally speaking three significant things happen: the leading MVAR increases, the rotor excitation is reduced, and the rotor angle increases. For this reason the circuit is variously called a VAR limiter, a minimum-excitation limiter and a rotor-angle limiter. These descriptions also indicate in a rough manner the means of detecting the approach towards the stability limit. The circuits employed vary considerably, but generally use signals dependent on terminal voltage, stator current and sometimes rotor current to achieve the required limiting characteristic.

If this feature is used the limit should be set as far

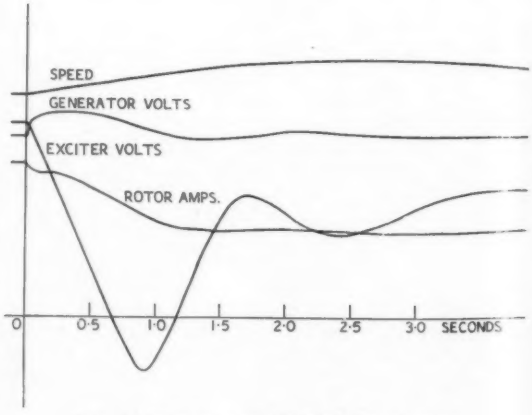


Fig. 9. Response to 100% load rejection

in the leading region as possible, for if, during a disturbance, the limit circuit comes into operation it may well throw the leading current on to other generators not fitted with this feature and cause them to lose synchronism.

Follow-up

Usually the main-exciter shunt field provides most of the excitation under automatic control, the second-stage amplifier bucking or boosting as necessary. If the automatic regulator is tripped out due to a fault within itself then the generator is left running under manual control of the excitation without any correcting action. If the field rheostat was not set in the correct position for the particular load conditions the excitation of the generator changes when the regulator is tripped. Usually the operator periodically adjusts the setting of the field rheostat so that the regulator is neither bucking nor boosting, but it is obviously impossible for him to maintain correct adjustment continuously. In order to provide this continuous adjustment a follow-up unit is employed. This unit adjusts the shunt-field rheostat so that the regulator is kept in a state of balance, and so prevents a change of generator excitation if the automatic control fails. In addition the unit works the other way round, i.e., it controls the automatic regulator voltage setting to the actual value of the generator voltage while manual control is in use. It is then possible for the operator to change instantly to or from automatic control without disturbing the generator and without going through the conventional balancing procedure.

Power Factor and MVAR Control

Conventionally an automatic voltage regulator controls generator terminal voltage, although in practice this is used mainly as a means of controlling reactive MVA. Where considered suitable, control of generator power factor has been provided. So long as the generator voltage remains within a few per cent. of the correct value the voltage control is made inoperative and a power-factor control circuit assumes control, the power factor being held to the set value regardless of variations in load, system voltage, etc. The normal voltage control takes over in the event of a serious change of generator voltage such as occurs upon load rejection.

Where a generator is sometimes used as a synchronous capacitor, MVAR control can be provided. Within the normal range of generator voltage this control holds the leading MVAR constant at the set value.

Performance

Fig. 7 shows the response of a fast-response regulator using magnetic amplifiers for both stages of amplification to a step change of – 1% in the regulator voltage setting. The change of generator voltage is too small to be seen but the exciter voltage changes by about 10% in making the correction.

Fig. 8 shows a similar response for a step change of +4·8%. It can be seen that the exciter voltage rose 50% to force a rapid increase of rotor current, and the voltage crossed the final value, before overshooting slightly, in 0·75 sec.

Fig. 9 shows the response on rejection of 100% load. The rise of voltage was arrested in 0·3 sec and the final voltage level was crossed in 1·2 sec. The exciter voltage went negative in trying to force the rotor current down rapidly.

Conclusion

The modern fast-response regulator has many advantages to offer, most important being: 1. Accuracy of control; 2. Fast response; 3. Extended range of stable generator operation in the leading region; 4. High order of reliability due to the use of static components for all the regulating circuits; 5. Considerable reduction of routine maintenance. This type of regulator not only controls the power system accurately under steady conditions, but also plays an important part in reducing the effect of disturbances to the system.

(*From page 337*)

explosive consumption varied between 3·08 to 3·87 lb. per cu. yd. of solid rock.

A 1¼ cu. yd. Conway loader was used with 10½ cu. yd. cars, which were hauled by electric locomotives of either 150 or 240 h.p. For the two centre headings the muck was hoisted in a 12 cu. yd. skip up the junction shaft. Dumpers of 15 tons capacity took the muck from the shaft surface bin to the disposal area.

Support. Steel ribs spaced at 1 ft. to 7 ft. centres were installed, together with some rock bolting, in some 17·5% of the tunnel length. Some 28% of the tunnel was lined with concrete. This lining was placed in three stages—the kerbs, invert and finally the sidewalls and arch.

Ventilation. An exhausting system was used in conjunction with 36 in. diameter two-stage axial-flow fans of 20,000 cu. ft. per min. capacity placed at 4,500 ft. intervals.

Power. Electricity was supplied at 11 kV, and was stepped down to 6·6 kV at the site, and further reduced in the tunnel. Compressed air was supplied through 8 in. lines at 125 lb. per sq. in. and at the rate of 11,500 cu. ft. per min.

Track. Single 42 in. 60 lb. rail was installed with passing and storage switches at 5,000 ft. intervals.

Drainage. Water was delivered into 14 in. diameter steel pipes by electrically driven pumps. The Eucumbene portal heading proving to be the wettest, particularly when the major fault zone was entered.

T.1. Pressure Tunnel. This was excavated in granitic rocks, and was similar in cross section, methods of excavation and lining to the Eucumbene-Tumut tunnel.

Recent Work. In 1958 work began on the T.2. power station project, the Tooma-Tumut diversion and the Murrumbridge-Eucumbene diversion, a total of 28 miles of tunnel, the majority having a diameter of between 11 and 12 ft. As the grouting of upward-placed rock bolts is proceeding well, only rock bolting has been specified as the primary support, using both the slot-and-wedge and the expanding-shell types of bolt. The use of a large-hole burn cut is proving very satisfactory in this diversion.

Design Floods

The Institution of Civil Engineers has reconsidered its 1933 Interim Report of the Committee on Floods in Relation to Reservoir Practice

A SUPPLEMENTARY meeting of the Institution of Civil Engineers on June 2 discussed the question of adding a proposed new appendix to the Interim Report which the Institution's Committee on Floods in Relation to Reservoir Practice had prepared in 1933. During the past four years a large body of records of flood flows observed between 1933 and 1958 had been sent to the Institution by engineers engaged on the development of hydro-electric power, water supply and land drainage, and the sub-committee on Rainfall and Run-off of the Institution's Research Committee had studied the recommendations of the 1933 committee in the light of these data.

The original Floods Committee had been appointed to make recommendations on the best methods of dealing with floods in relation to reservoir practice in Great Britain. They expressed the view that the subject did not lend itself to rigid treatment by means of precise rules, and put forward their 1933 recommendations as a basis for engineering practice, with exceptions to be made to suit local conditions. The 1933 Report reproduced the conclusions of Colonel Sir Gordon Hearne and Dr. John Glasspoole on the variations with duration and with area of maximum average rainfalls likely to cause catastrophic floods, and accepted the idea of the "period of concentration" which must elapse to allow water from the most distant part of the catchment to reach the reservoir. As the ratio of run-off to rainfall depends on so many factors that, in the committee's view, it is impracticable to take them all into consideration, they found themselves unable to put forward any rules for arriving at maximum run-off on the basis of rainfall. They recommended that reliance should be placed on records of past floods when design floods were estimated. The envelope curve of the points representing observed flood peaks plotted against catchment areas was adopted as defining "normal maximum" floods. A study of the observed flood peaks showed that they were usually caused by rainfalls of approximately 3 in. in a few hours.

It was well known to the committee that the hydrograph of outflow from a large reservoir possesses a much smaller peak and a longer duration than that of inflow, and the modifying power of reservoirs was called "lag." As the lag is a function of, amongst other factors, the shape of the inflow hydrograph, the 1933 Report contained a diagram with a number of idealised inflow hydrographs to be used with catchments of various sizes. Recommendations were added that prolonged rainfall be allowed for by providing spillways of a capacity of at least 150 cusecs. per 1,000 acres of catchment. Other recommendations referred to minimum lengths of overflow weirs, the treatment of catchments with more than one reservoir, safety margins on dams (above spillway crest level), and catastrophic floods caused by rainfalls of extraordinary intensity and/or duration.

The Sub-committee had stated their findings in the form of a proposed new appendix of the 1933 Report. Briefly, they found that the statements made in that Report were further supported by the data collected between 1933 and 1958, which, with the earlier data, had been plotted against the areas concerned in the two Figs., 3a and 4a, as well as, in combination and to logarithmic scales, as shown in Fig. 11. This Fig. 11 included two curves, one the "normal maximum" curve of the 1933 Report and the other, which was to a slope of, logarithmically, $-\frac{1}{2}$, enveloping all observed flood peaks. The sub-committee remarked however, that the latter envelope would have to be raised as additional data were obtained.

They suggested that many engineers concerned with river floods and rainstorms but not necessarily also with reservoirs would welcome a report of wider scope. In the interests of overall economy of the effort thus entailed, they thought that a study of hydrological techniques should be undertaken with the aim of reducing the quantity and increasing the usefulness of all field observations to be collected. Research into flood frequencies, based on long-period records of river flow and rainfall, would, in their view, yield information less liable to be superseded by new flood measurements than the envelope curves of the 1933 Report.

The discussion on June 2 was opened by the members of the sub-committee who submitted it for acceptance as being in the spirit of the 1933 Committee's intentions: the Chairman, Mr. W. Allard; Dr. John Glasspoole; and Mr. P. O. Wolf. Mr. Allard recalled that, following the flood disasters of the 1920s, the Reservoirs (Safety Provisions) Act, 1930, became law and required all storage reservoirs containing more than 5 million gallons above the surface of the ground to be regularly inspected, and new ones to be designed, by engineers whose qualifications had been approved by the Home Secretary. In view of the wide divergence of opinion among civil engineers on the maximum floods for which spillways were to be designed, the Institution set up a committee which called for flood records, prepared a draft report which was discussed at a general meeting in February 1933, and in July 1933 published its Interim Report. The committee consisted of 11 engineers with special experience in the field of flood estimation and of such eminence that three of them subsequently became Presidents of the Institution. The present sub-committee had been invited to examine the records of river flood discharges since 1933 and to consider whether they modified the conclusions of the 1933 Report in any way. Had more than that been required, the Institution would no doubt have

appointed a larger body as authoritative as the 1933 Committee.

Mr. Allard then put forward a number of questions which the sub-committee's study had raised—whether a floods report on other lines was thought possible or desirable and, if so, what lines it should follow, on what further hydrometric information it was to be based, and how new developments in hydrology might make it possible to estimate the probable maximum flood run-off of any area in the British Isles on the basis of more intensive rather than extensive field investigations. In this connection he drew attention to the great advances made in the United Kingdom since 1933, not only in the systematic measurement of rainfalls and run-offs, but also in the development of hydrological teaching, research and theory.

Dr. Glasspoole referred to the contribution to flood studies which a knowledge of the frequencies of intense and widespread falls of rain would be bound to make.

With time intervals of a month or more, extremes of rainfall were related to average annual rainfall, and the frequencies could be calculated and generalised fairly accurately. Extremes of daily rainfalls, on the other hand, were independent of annual averages and seemed to be similar in all parts of the country. However, he still did not think that there were sufficient records available to define frequencies in terms of the amount, the duration and the area covered by rain. The Meteorological Office was making a detailed study of the frequencies of intense rainfalls over certain areas, and the results of this study might ultimately be of assistance to all civil engineers concerned with inland waters. He was looking forward to the ultimate goal of generalisations which would reduce further hydrometric efforts required to define the situation throughout the country.

Mr. Wolf went through some of the salient points of the proposed new appendix, with special reference to run-off extremes. He raised the question of the "time of concentration" the significance of which was being expanded in the light of modern studies, and then turned to the problem of the frequencies of "wetness" of a catchment which varied over the British Isles but were of little significance in the estimation of the maximum possible run-off. Safety margins on spillways had perhaps been treated too briefly in the 1933 Report, but he thought it would be clear to all concerned that margins would have to vary depending on whether low-head spillweirs were used, on the one hand, or high-head siphons, bell-mouth spillways or low-level sluices, on the other.

Referring to the need for future studies, Mr. Wolf stressed the duality of current practice. "Heaviest possible" floods were estimated by means of an analysis of maximum rainfall intensities and of catchment characteristics. "Normal maximum" floods and their "catastrophic"[‡] multiples were derived, empirically, from observations of flood intensities. Attempts were, of course, always being made to improve one technique by grafting on it some result of the other. However, the sub-committee had plotted the new data which the Institution had received in the same manner as the 1933 Committee (Figs. 3A and 4A), and also on logarithmic paper (Fig. 11). As had been done successfully elsewhere, e.g., by Schnackenberg* whose plots of worldwide data were shown on slides, the sub-committee had tentatively provided an envelope curve according to which the maximum flood intensities in the British Isles increased in proportion to the square root of the catchment area.

Mr. Gerald Lacey expressed his admiration of the authors of the 1933 Report. He appreciated the need for a study of floods on town areas and in very large rivers, but preferred that the 1933 Report, brought up to date, should remain what it had been intended to be, namely, a Bible for those engineers who had a statutory responsibility for reservoirs in hilly or upland areas. He suggested that the new envelope tentatively put forward by the sub-committee (and representing a peak intensity of run-off increasing with the square root of the catchment area) should be modified to be tangential to a limit of intensity of 8,000 cusecs. per 1,000 acres. It was obvious that there must be an absolute limit. At the other extreme, he also recommended a lower limit than that shown for very large areas in which the lowland element would inevitably become more important. He had been unable to find a clear definition, in the 1933 Report, of "normal maximum" floods, and he suggested that, if it would be difficult to define, it probably was not a very good concept.

Mr. C. F. Lapworth commented on the use of the word "interim" in the title, which he thought should —after a lapse of 25 years—now be omitted, although it would be understood that further work on floods would continue to be required. In connection with margins of safety he recommended a reference to the value of model experiments both to check the safe performance of spillways, particularly when of an unusual kind, and to calibrate them so that the intensities of any future floods might readily be determined.

Mr. A. Bleasdale observed that too many of the points plotted in Figs. 3a and 11 that were greatly in excess of the "normal maximum" were interdependent and referred to the Lynmouth flood of 1952. The proposed new envelope curve had been given a slope claimed to be consistent with simple statistical theory, and as he divided statistical theory into two classes—good and bad—he asked for an assurance that the new envelope was based on good statistics. He was disappointed at the absence of information on modern methods of estimating probable maximum rainfall over an area, and asked for references to the considerable literature on that subject which had been prepared in various countries. He specifically instanced Professor E. J. Gumbel's work on the statistics of extremes. With the assistance of a colleague at the Meteorological Office, Mr. Bleasdale had studied flood frequencies in four areas and had come to the conclusion that the floods likely to occur once in a 1,000 years in those four areas all lay well below the "normal maximum" of Fig. 3 of the 1933 Report. Such work would, he thought, yield the precise meaning of the expression "normal maximum."

Mr. W. E. Blackmore thought the time was ripe for a new report on floods, without any reference to reservoirs: a flood was a flood, wherever it happened. Much of the material in the 1933 Report, e.g.,

* Schnackenberg, "Extreme Flood Discharges," *N.Z. Inst. of Engrs.*, 1949.

reservoir lag calculations and the analysis of weir performance, was described in textbooks and need not be repeated in an Institution report. As the 1933 Report applied especially to "upland" areas, he suggested that "uplandishness" be defined quantitatively, perhaps in terms of the average annual rainfall. He had related the peak floods of around a dozen catchments to their average annual rainfalls and found a close connection. Even such rivers as the Thames and the Severn, which did not approach the "normal maximum" curve, came into line.

As the appendix called for a determined effort to establish and maintain gauging stations on upland streams, he wondered if the Council of the Institution would recommend to the appropriate Minister that the required work be started.

Mr. G. R. Hoffman observed that, in the case of dams where overtopping would result in failure and possible loss of life, the choice of a design flood was a heavy responsibility—shared by the Institution which was in the 1933 Report offering recommendations on this subject. That Report had stood the test of time for almost 30 years, and that seemed to be the reason why it was proposed to reissue it with an additional appendix.

Mr. Hoffman put forward what he considered a possible approach to the scientific method. He criticised the envelope drawn on Fig. 11 of the appendix on the grounds that of the 64 points representing catchment areas up to 25,000 acres only 12 exceeded the "normal maximum" by more than 20%. Eleven of these referred to the 1952 Lynmouth flood and the twelfth to the 1917 Redaven flood. On the evidence of those two floods the envelope had been raised to between three and four times the "normal maximum," and the sub-committee had pointed out that the new envelope line was not final. He suggested that more than one method be used to estimate the design flood, and asked the sub-committee to include an outline of the scientific method in the appendix. The procedure would start with a study of the maximum rainfalls which could occur in various time intervals and over various areas, taking account of the typical distribution of the rain over the catchment area under investigation. Detention and infiltration rates would be deduced from a study of the catchment, and the excess rainfall would be used to calculate the flood hydrograph by the unit-hydrograph method.

Such a study was laborious and required expert advice from meteorologists, but seemed much less likely to give dangerously erroneous results than such curves as were drawn in Figs. 3A, 4A and 11 on which flood-peak intensity had been plotted against catchment area.

Mr. G. A. R. Sheppard, said that in 1933 there were not sufficient data available for any definite recommendations on the magnitude of catastrophic floods. The proposed appendix indicated that floods well in excess of twice the "normal maximum" were to be expected, and the time had come to abandon the term "normal" and to replace the term "catastrophic" by "design flood."

In the case of river-protection work, there might be an economic limit, but in relation to reservoirs there was no such limit; catastrophic floods must be allowed for in design, and the next edition of the Report should include design-flood hydrographs.

As rainfall records were more numerous and of longer duration than discharge records, they offered a safer basis for design and justified the use of the curve in Fig. 1, based on the formula $I=8/(T+1)$. He suggested that, in the revision, the formula should be replaced by one which enveloped all rainfall intensities observed in the British Isles, including the most recent ones, such as the formula $I=6/\sqrt{T}$ published by Mr. Wolf* or a formula Mr. Sheppard had found useful, $I=9.5/(T+1.8)$. He then gave an example of the estimation of a flood hydrograph from a catchment area of 15,000 acres which showed that, with a large area of reservoir, the duration of maximum rainfall did not greatly affect the outflow; it would, however, do so in the case of small reservoirs.

Mr. J. E. Nash thought that—apart from the factual data—the rest of the 1933 Report was very much out of date, and suggested that either the 1933 Report be entirely withdrawn in favour of Figs. 3A and 4A or that a completely revised report be published in which, in particular, the concept of the time of concentration and the rational method should be abandoned in favour of the unit-hydrograph method.

He then put forward several criticisms of the 1933 Report and of the assumptions on which its conclusions appeared to rest, largely in terms of the modern unit-hydrograph theory. The "normal maximum" flood was clearly not the maximum possible, but would be the flood of a certain (though unspecified) frequency. Fig. 2, on which the maximum average rainfall recorded is plotted against catchment area, would be of use in the computation of the absolute maximum flood, but not of recurring lesser floods. If frequency concepts were used, the one-year flood, which could be much more accurately estimated than an infrequent one, should be related to catchment area, and the normal maximum defined as a multiple of the one-year flood. The attenuation caused by the reservoir was a function of the whole inflow hydrograph, not only of the peak intensity of inflow. The attempt to summarise the effects of reservoirs of various areas and with various weir dimensions in Fig. 7 was suspect in that one dimensionless ratio was defined in terms of a length and of another dimensionless ratio. As to the critical inflow hydrograph, if it was possible to speak of a critical storm for a given catchment at all, it was necessary to take account of the delay time of the reservoir itself.

Mr. R. W. Buchanan asked for an explanation of the statement in the proposed appendix that the tendency to "wetness" of a catchment increased with latitude. Secondly, the sub-committee appeared to think that the ratio of "catastrophic" to "normal maximum" flood intensities decreased with increasing catchment area. He had found the opposite to be the case in two adjacent catchments, one of 25,000 acres and the other of 11,000 acres. Lastly he emphasised the need for a frequency study of floods as suggested in the proposed new appendix. Both the user of the reservoir and the contractor constructing it were interested in frequencies of lesser floods, say half the "normal maximum."

Mr. P. L. Aitken stressed how difficult it would be to draw up an acceptable document replacing the

* Peter O. Wolf, "The Influence on Flood Peak Discharges of some Meteorological . . . Factors," Int. Assn. of Hydrology, Gen. Assembly, Toronto, 1957, Vol. III, p. 26.

1933 Report which was giving good service to engineers responsible for dams under the Reservoirs (Safety Provisions) Act, 1930. He considered the envelope curves in Figs. 3 and 4 to be the most valuable parts of the Report. During the 27 years since 1932 only three floods had been recorded, on catchments greater than 25,000 acres, with intensities greater than the "normal maximum" curve of Fig. 4, and they were surely of catastrophic dimensions. In Fig. 3A (describing catchments up to 25,000 acres) nearly all the floods substantially in excess of the curve were from the Lynmouth area, and undue emphasis seemed to have been given to that single flood. The new envelope in Fig. 11 seemed to him to suggest a dangerous idea, and he preferred to leave engineers to choose their own factor to be applied to the "normal maximum," based on the characteristics of the catchment and reservoir concerned.

He agreed that a study of flood frequencies was important. He was also much interested in Dr. Glasspoole's account of the Meteorological Office study of intense rainfalls over different areas, and thought that it would assist engineers to have an indication of the frequencies of intense rainfalls in the regions where they were working, if possible on the lines of a thunder map.

Colonel H. C. Bowen, was chiefly concerned with areas other than upland, the flood records from which showed maxima considerably below the "normal maximum." The scatter of the points representing the observed maxima was so pronounced that he suggested the use of a family of envelopes, rather than a single curve, the parameter being the geology of the area. He quoted the examples of various tributaries of the Thames where small chalk catchments exhibited lower peak run-off intensities than clay-covered catchments of 10 times greater area. Another difficulty arose from the complexity of the summation of flood peaks from numerous tributaries. The old approach via the time of concentration could give misleading results, as was shown during the 1947 flood at Teddington when, at the time of the peak discharge in the Thames, the flows in the three downstream tributaries (draining about one-fifth of the total Thames catchment) had receded from their peaks to quite low discharges. The alternative approach based on the unit-hydrograph method was laborious and apt to be uncertain. He thought that geology controlled the volume of run-off and slope the speed of travel of the flood wave, and both geology and slope, if used in some method such as Professor Linsley's coaxial correlation, might together give more useful results than the single envelope curve.

Mr. C. D. C. Braine doubted if the word "upland" had been of help in the understanding of the problem of floods. In any case the largest areas which had provided records extended to over a million acres and must contain much lowland which would tend to reduce peak flood intensities.

Mr. P. Ackers warned the audience that much of the information tabulated in the proposed appendix had been derived from spillway discharges and might not give the full peak values of the flood inflow into the reservoirs concerned. Had there been no reservoirs present in some of the catchments he named, the peak flood intensities, quoted in the tables and plotted on the diagrams, might well have been higher. He referred to safety margins and suggested that the characteristics of the type of spillway chosen must affect the approach to the determination of the design flood. If an engineer unimaginatively designed a weir in accordance with the recommendations of the 1933 Report, he might still have an ample reserve for catastrophic floods; other devices, however, if similarly designed, would have hardly any margin. Once the inflow exceeded the gorging discharge of a bellmouth or the black-water discharge of a siphon, the lake level would rise rapidly, with possibly disastrous effects. He asked the sub-committee to give clearly defined guidance on (i) the design flood for spillways other than freely discharging weirs; (ii) any additional factor of safety to be used for spillways with a limiting discharge; (iii) the advisability of designing all spillways to discharge catastrophic floods, rather than "normal maximum" floods with the arbitrary allowance of 2 ft. of freeboard, the advantage of which varied from case to case.

Mr. N. A. F. Rowntree also referred to the emphasis placed in the 1933 Report on "upland" catchments. The division between "upland" and "lowland" was difficult to make, and he suggested that all data should be used, and that the average slope of every catchment should, if possible, be quoted; that procedure might lead to a better relationship between catchment characteristics and peak rate of run-off.

He uttered a warning about frequency methods of flood calculations. There were two points of view, that of the River Board and that of the designer of storage reservoirs, and they involved different kinds of calculations.

Mr. Allard briefly replied to the discussion. He stressed the usefulness of many of the points raised. There had been diametrically opposed views on certain matters, and at moments he had been reminded of Lord Macaulay's lines, "But those behind cried, 'Forward!' and those before cried, 'Back!'."

Dr. Glasspoole, in his reply, briefly explained that barometric depressions centred more frequently in the north-west of the British Isles and the frequency of rainfalls increased from the south-east to the north-west.

The suggestion that there was an absolute limit to the rainfall intensity of 8 in. an hour, was not supported by observation. The highest intensities over small areas were caused by instability storms, such as thunderstorms, with a cellular structure in which there was violent uplift. When the uplift stopped, the rain fell out of the "cell," and it reached very high intensities, for short periods, over small areas. If a thunderstorm occurred over open water surfaces, water might be sucked up in the form of a waterspout which on falling back to the ground represented an exceedingly high intensity.

Mr. Wolf repeated that the new envelope curve (on Fig. 11) had been put forward with the warning that it would certainly have to be raised as more data were collected. The definition of "upland" areas in the 1933 Report was that their slopes were between 1 in 10 and 1 in 50. It seemed that the 1933 Committee would have agreed with the suggestion that slope was an important parameter. The attack on the term "time of concentration" was justified if it was used in a narrow sense, but the sub-committee felt that as a result of recent studies of the hydraulics of overland and stream flow the meaning of the term had been

widened to cover "time to peak" and similar concepts. The dimensional inconsistency of Fig. 7 had been pointed out, quite correctly, but he assumed the curve on that diagram to be an average drawn through a number of points representing a variety of conditions encountered in practice. With upland catchments from 1,000 to 25,000 acres the error would probably not be more than 5 or 10%.

The Lynmouth run-offs were prominent, but he did not think that they were unduly so. Firstly, each point represented an estimate of a peak flood at a separate site based on surveys of that site, and no plotted value had been solely computed by addition of other peak flows from several tributaries. Secondly, the Lynmouth area showed what could happen on a catchment which had not, within living memory, suffered from very heavy rainfall or run-off intensities: Dr. Glasspoole had indicated that there was no reason why any area in the British Isles should be immune from storms of Lynmouth intensity (or even more), however infrequent they might be.

Having raised the question of frequency, he stressed the aim of the 1933 Report which was to give guidance to engineers responsible for the design of dams which had to be safe against the worst possible "catastrophic" floods. Colonel Bowen's suggestion, for example, that the geology of a catchment would influence the run-off peak, was manifestly true, but the sub-committee had been unable to allot a numerical value to the least possible reduction of flood peak to be expected from a normally pervious catchment.

Professor E. J. Gumbel's statistical theory of extremes had been mentioned, and he drew attention to the fact that in Gumbel's latest book several types of distributions of extremes were mentioned, at least two of which had been found to be of value in the study of floods. As there did not appear to be a unique formula, the application of Gumbel's brilliant ideas seemed still to require a good flood record and a skilled analyst.

The discussion had contained many very valuable comments which would be studied with advantage by engineers engaged on the estimation of design floods. Even if many of the specific comments were qualitative rather than quantitative, or in some cases applicable to a limited range of conditions rather than universally valid, they would provide most useful signposts to the practitioner.

British Hydromechanics Research

The Annual Open Day at the Harlow laboratory of the British Hydromechanics Research Association has become so well-established and popular an institution that for the past year or two the "Day" has in fact become two days. This year's function was as interesting as ever, and although much of the laboratory's work is outside our particular field, a number of investigations are either concerned directly with hydro-electric schemes or with problems in which the hydro-electric and the water-supply engineer have a common interest.

From our standpoint the outstanding investigations are those, now well advanced, on the intakes and supply shafts for the Ffestiniog pumped-storage scheme. Air models, to a scale of 1 : 14·5, of the intake and upper bend, lower bend and bifurcation showed that the designs for the lower bend and bifurcation were satisfactory, and pointed the way to a reduction of 50% in the losses in the upper bend, corresponding to an additional 400 water horsepower at the turbine. An outdoor 1 : 30 scale hydraulic model of the two intakes is being used to study the formation of air-entraining vortices and to suggest ways of improving the design.

A particularly interesting 1 : 11 scale model is of a draw-off tower designed by Messrs. Binnie, Deacon and Gourley for Liverpool Corporation waterworks Tryweryn reservoir, consisting of five air-locked syphons arranged one above the other. The purpose is to obtain intermittent draw-off at unusually high flow rates without incurring the heavy cost of mechanical gates.

To investigate surge problems associated with this draw-off tower a d.c. analogue computer was used which can also be employed to investigate surge-tank problems.

A model of a bellmouth spillway for Hong Kong water supply was also on test, as were models of tidal flap gates for the river Birket, a tributary of the Mersey. Models have also been constructed to study the design of the cooling-water intakes for Hinkley Point nuclear station.

A flow straightener to allow the use of an orifice plate with very short settling lengths of upstream pipe has been developed, and plans are in hand to extend this work to water flow at much higher Reynolds numbers in connection with the National Engineering Laboratory at East Kilbride.

At these Open Days it is a pleasing custom of the Laboratory to exhibit a model in lighter vein. This year a "magic fountain," under the influence of a self-contained air-water circuit based apparently on perpetual motion, generated sufficient hydraulic head to project a jet some four inches above the top of the apparatus. Some of the guests were solemnly drawing diagrams of it to discover either why it worked or why it shouldn't.

Sulzer's 125th Anniversary. Sulzer Brothers Limited, of Winterthur, celebrate this year the 125th anniversary of the foundation of the firm. Today their products include diesel engines, gas turbines, fans, steam power plants (both boilers and turbines), compressors and blowers, refrigerating machinery, heating and air-conditioning plant, weaving machines and foundry products. This list, extensive though it is, leaves out two products of prime importance to the hydro-electric industry—pumps and high-pressure pipelines. The firm began to manufacture centrifugal pumps in 1860 and have not only participated in every phase that has marked the development of these machines but have manufactured some of the biggest hydro-electric storage pumps in the world. Sulzer's have also played an equally prominent part in introducing new design and manufacturing methods into the development of welded high-pressure pipelines.

Etablissements Bouchayer & Viallet. This firm, which has its works at Grenoble, France, has issued a series of booklets dealing with Radial Gates, Butterfly Valves and Hollow Jet Valves, and Roller Gates and Bulkheads. The booklets are effectively illustrated and drawings and data are given of recent impressive installations.

Fig. 1. Access tunnel to Upper Vinstra station under construction

The Upper Vinstra Scheme

The construction of the Upper Vinstra station brings this important Norwegian development to its final capacity of 310 MW

THE Lower Vinstra development in Opland, Norway, is the property of an intercommunal company—Vinstra Kraftselskap—owned by Oslo Lysverker and Hamar, Vang og Furnes kommunale Kraftselskap. In our March and April 1956 issues we gave a full account of this development, which contains many points of interest. Vinstra underground station, which has a number of excellent design features, was built for the eventual reception of four 50 MW generating sets, the turbines of which, operating under a net head of 420 m., were amongst the highest-head Francis machines in Europe. Three of these machines were in operation by the time our articles were published; the fourth was put in operation last year, and consists of a Kvaerner Brug turbine driving a Norsk Elektrisk & Brown Boveri generator.

In our March 1956 article we gave particulars of the catchment area, which has an extent of 1,290 sq. km. and is formed by a series of lakes in the upper reaches of the Vinstra terminating in lake Öyvann which has been impounded to a retention level of 1,014 m. The intake basin for the power station is provided by lake Olstappen at a retention level of 668 m., the connection being by means of a supply tunnel, 23.7 km. long, which is one of the longest water tunnels in Europe. As pointed out in our previous article, this left an undeveloped head of 346 m. Of this head, 330 m. is utilised in the Upper Vinstra power plant.

Our earlier map of the catchment area is reproduced in Fig. 2, but we have added to it the Upper Vinstra development in bolder lines. The Upper Vinstra development utilises the flow of the main river Vinstra and the tributaries Hinögla and Hölsa. The flow of Hinögla is transferred to the main river by a tunnel about 6 km. long and 9 sq. m. in area from lake Nedre Heimdalsvann.

The natural tunnel line from the intake in Kalfjord in the main river to the power station at Slangen has been shortened by roughly a third by making use of the lake Öyangen in Hölsa river as the main intake of the plant. A tunnel 2.8 km. long and 22 sq. m. in area has been driven from Kalfjord to Öyangen.

Storages

The seasonal storages provided in the Vinstra lakes Bygdin and Vinsteren amounts to 445 million cu. m. Last year, the last of the main storages in the Upper

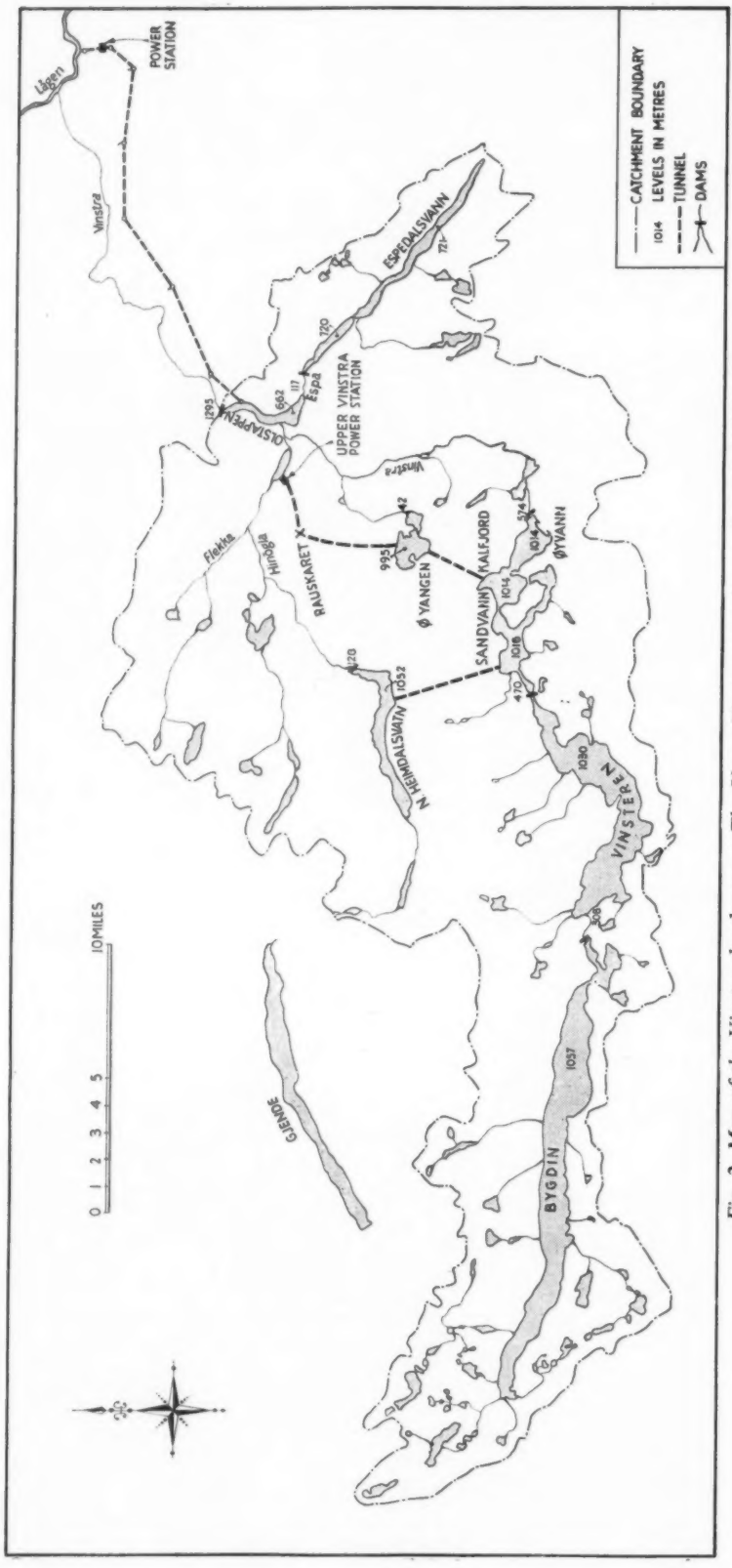


Fig. 2. Map of the Vinstra development. The Upper Vinstra tunnels are shown in bolder lines

Vinstra, the Sandvann-Kalfjord-Öyvann storage was improvided, giving an additional storage capacity of 76 million cu. m. In the lakes Nedre Heimdalsvann and Öyangen there is also 15 million cu. m. of storage, making a total storage available to the Upper Vinstra station of 536 million cu. m. The Lower Vinstra development is supplied from this storage through the Upper Vinstra station and in addition draws on a storage of 30 million cu. m. afforded by Olstappen.

Öyvann dam

Öyvann dam consists of a concrete section about 96 m. long and adjusting earthfill dams at both banks. The dam is supplied with two high-water segment-type control gates and two roller gates. The maximum and the minimum water levels are 1,019·0 and 1,013·1 m. above sea level giving a total regulation range of 5·9 m. and a storage capacity of 76 million cu. m.

As the ground was very permeable, comprehensive grouting had to be carried out.

The Upper Vinstra Power Plant

The intake at Öyangen is situated about 200 m. from the shore and is connected with the lake by a concrete duct 110 m. long and 25 sq. m. in area. At the site of the intake the rock surface lies 10 m. below the level of the lake. The intake is designed as a box-shaped reinforced-concrete structure and is connected with the supply tunnel by an unlined pressure shaft 20 m. deep.

The supply tunnel is 7·5 km. long and is 32 sq. m. in area. At Rauskaret, 5·5 km. from the intake, the tunnel has to pass across a deep depression where the surface of the rock goes down to 50 m. below the level of Öyangen and between this point and the surge tank the level of the tunnel is therefore lowered about 50 m. At the surge tank the tunnel is raised to normal level, thus giving normal water pressure at the

main gate at the top of the pressure shaft. At a distance of 200 m. the surface of the rock was too low to admit using an unlined tunnel, and at this point the tunnel is lined with reinforced concrete. The remaining tunnel length is unlined.

The rock consists partly of mica schist, partly of gneiss. As a rule, the rock is sufficiently strong to permit the use of an unlined tunnel even where the surface of the rock is as close as 10 m. to the top of the tunnel. The tunnel, however, passes a number of zones of disturbed rock, and at these zones, totalling 300 m., steel arches had to be erected and the space between arch and rock timbered as a temporary measure to protect the workmen. When the tunnelling was finished, the sections protected with arches were lined with concrete.

The mica schist was very tough, but nevertheless excellent progress has been maintained with an advance up to 60 m. in a week. The arrangement at Rauskaret may be taken as representative. The total tunnel length from Rauskaret to Öyangen (5·5 km.) was driven from Rauskaret only. Three shifts were in operation, each shift consisting of eight men including the worker ganger at the face, one loco driver, one man at the tip and two mechanics. In addition four men were employed on day shift on rail placing and general maintenance. A foreman and assistant have charge of the whole site.

A 70 hole drilling pattern gave a pull of 2·4 m. A Goodman Type 100 Conway electrically driven shovel was used for mucking and 6 cu. m. wagons for spoil transport.

The surge tank consists of a shaft 19 sq. m. in horizontal area, with an upper chamber 450 sq. m. in area and a lower chamber 180 sq. m. in area connected to the top of the tunnel. The main roller gate, 3·6 m. wide and 6·0 m. high may be automatically closed from the control room in the power station. The trashracks may be dried and cleaned when the gate is closed.

The total length of the pressure shaft is 520 m. The lower section is about 370 m. long, steel lined, and 7·1 sq. m. in area. The rest of the shaft is lined with reinforced concrete. The shaft has a gradient of 41°

Fig. 3. Upper Vinstra machine hall under construction

Fig. 4. Lined portion of the supply tunnel

Fig. 5. A view in the pressure shaft

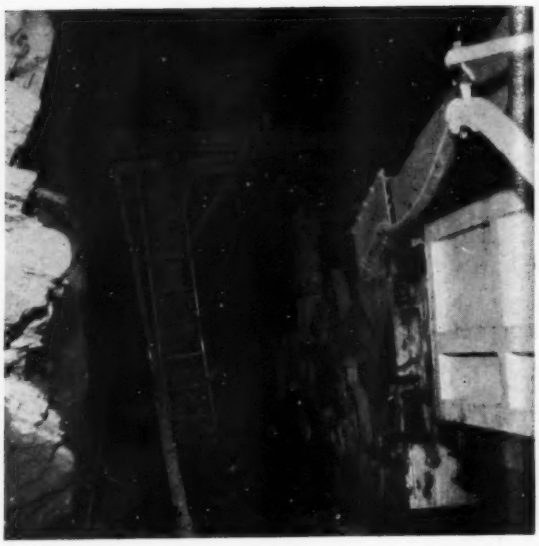


Fig. 6. Type 100 Conway shovel mucking out

and was constructed by driving a pilot raise from the bottom and subsequently opening out to full cross section from the top. Two drills were at work in the raising operation, drilling a 32 hole pattern to a depth of 2 m. Staging points were at 100 m. intervals, and mucking was controlled by a pneumatically operated chute.

The underground power station involved an excavation of a hall 14 m. wide, 49 m. long and 31 m. high from the bottom of the draft tube to the top of the machine hall, and in addition a transformer annexe 10 m. wide, 33 m. long and 9 m. high and a tailrace tunnel 897 m. long and 40 sq. m. in area. Construction of the power station also called for driving a transport tunnel 837 m. long and 27·6 sq. m. in area.

The civil-engineering contractors responsible for the tunnelling and excavation are Thor Furuholmen of Oslo.

All drilling is being carried out by Holman Silver Three rock drills* mounted on airlegs and using Vulcanus tungsten-carbide-tipped steels. At all sites the contractors have standardised on Holman T 60R compressors, giving a free air delivery of 535 cu. ft. per min. at 100 lb. per sq. in. Batteries of compressors are placed in a common circuit with Holman control panels indicating lubricating-oil pressure, intercooler air pressure, and receiver air pressure, with automatic cut-off at 115 lb. per sq. in. Aftercoolers are fitted by regulation, and these are A/S Norsk Mekaniska Verkstad coolers rated at 16 cu. m. per min.

The power station will have a capacity of 130 MW provided by two vertical Francis sets. The turbines, which will be the largest so far built in Norway, are supplied by A/S Kvaerner Brug, Oslo, and are rated 92,000 h.p. at a net head of 320 m. and at a speed of 428 r.p.m. The generators are of Norsk Elektrisk & Brown Boveri manufacture and are rated at 75 MVA, 0·9 p.f., 13 kV.

Fig. 7. A battery of Holman compressors

The generators are connected to three single-phase transformers with separate windings for each generator. The transformers are supplied by A/S National Industri, Drammen, Norway.

In the 13 kV switchgear each generator is supplied with a 4,000 A breaker with a breaking capacity of 1,500 MVA.

From the transformers four single-phase 220 kV cables run through the transport tunnel to an outdoor 220/300 kV switchyard. The switchgear is

*See WATER POWER, June 1958, page 238

designed to permit a change to 300 kV when required in a few years' time.

The telecontrol equipment at Övre Vinstra is remarkable. It is designed to permit control of the power plant from Lower Vinstra. The machines will be started and stopped, and the load will be controlled without any assistance at Upper Vinstra over a high-frequency power line from Lower Vinstra to the Fåberg substation and from Fåberg to Upper Vinstra. The carrier will be in operation even if the breakers in these stations are open. The equipment is supplied by A/S Norsk Elektrisk & Brown Boveri, Oslo.

Acknowledgments

This article is published with the kind permission and collaboration of Mr. R. Fagerberg, Managing Director of Kraftlaget Opplandskraft. The Consulting Engineer retained for the Upper Vinstra scheme is Elliott Strömme, Oslo.

Book Reviews

The St. Lawrence Seaway. By T. L. Hills. Published by Methuen & Co. Ltd., 36 Essex Street, Strand, London, W.C.2. 8¼ in. × 5⅜ in. × ⅝ in. Illus. 152 pp., plus index. 1959. Price 12s. 6d. net.

In this book a comprehensive but non-technical account is given of the St. Lawrence Seaway, completed this year, and of the incidental hydro-electric plants which have been erected to provide something like 2·2 million much-needed horsepower to Canada and the United States. A brief survey is first given of the discovery and exploration of the St. Lawrence—Great Lakes drainage system, which covers an area some 678,000 sq. miles in extent. Between Lake Ontario and Montreal the St. Lawrence drops a total of 246 ft. and between Duluth, the western extremity of Lake Superior, and the outlet of Lake Ontario there is a total drop of 356 ft. At Niagara, the flow amounts to 194,000 cusecs and in the International Rapids section, downstream of Lake Ontario, reaches a flow of 237,000 cusecs. It will thus be evident that the scope for hydro-electric power generation is immense, especially as the large area of the lakes affords an extraordinary regularity of outflow, which indeed is affected more by the direction of the wind than by the more normal seasonal factors.

The volume gives an interesting account of the earlier canals which were much too shallow for modern traffic, and of the construction of the modern deeper canal which enables ocean-going ships to pass into the interior. The economics of the canal system are necessarily a matter of speculation during these early days but the success of the power stations has already been thoroughly established even though the whole of the generating plant has yet to be erected.

Investigation Methods of Water Power Resources. By Ing. Vujica M. Yevdjevic. Published by the Serbian Academy of Sciences, Beograd, Yugoslavia. 1956. 214 pp., 115 ff. With English translation of the Yugoslav text and summaries in French, Russian, Spanish, German and Italian.

This inquiry on the water-power resources of some Yugoslav rivers is published as a thesis for a doctor's degree in technical sciences at the University of Beograd. For several reasons, the importance of this publication goes beyond an ordinary doctorate thesis.

In spite of the considerable amount of money spent every year on hydro power and of all the information collected on the hydrology of all types of rivers, the amount of theoretical research on this subject, having a definite character of generality, is limited. Very often, new publications are mere repeats of what has been said before on similar occasions.

The thesis of Mr. Yevdjevic is an attempt to bring new ideas and new points of view on an old subject. It is sometimes difficult to say with certainty what the real importance of new suggestions will be in the future. It is, nevertheless, essential that new avenues should be explored from time to time.

In May 1953, the United Nations Economic Commission for Europe, Geneva, published a pamphlet on the "Hydro-Electric Potential in Europe and its Gross, Technical and Economic Limits." Methods for determining the gross potential were evolved by the Electric Power Section of the Economic Commission. It was established that the "economically exploitable" production potential in Continental Europe is about 19·1 % of the gross potential (page 84, Table 26 of the Report, May 1953).

Some time later (1956) the Austrian Ministry of Commerce & Reconstruction published a bulky inquiry on the Austrian hydrographic system, based on a method similar to the one proposed by the Economic Commission for Europe, with some amendments and improvements, mainly for the determination of the gross potential from rainfall data.

The author of the present thesis applies similar ideas to the study of the hydro-electric potential of Yugoslav rivers (chapter 3), but insists on a definition of the power potential based on the river discharges (and not on the rainfall or gross run off, as done by other authors). He arrives at the conclusion (page 56, diagram Fig. 22) that the "probably usable potential E_5" is about 0·172 of the "gross potential" based on rainfall measurements, a figure which compares with the findings of the Economic Commission for Europe.

Chapter 4 deals in greater detail with the problem of the "economic limits" of the hydro potential of a river. Maximum and minimum values are established. In this chapter the author establishes some principles for a method considering the progressive development of a river step by step. (Such general inquiries have been done before by large producers of hydro-electric power, but to our knowledge little of this fundamental research work has been published before.) A theory is also attempted (pages 70-73) for the "division of capital investments of a complex water control scheme amongst a number of beneficiaries" (irrigation linked to hydro power).

Duration curves and the best definitions for tracing "average flow duration curves" are discussed in chapter 6. Chapter 7 considers the distribution of water power along a river; examples from Yugoslav rivers are given. Most of the facts summarised in this chapter are known from other sources.

Chapter 8 is entitled "Mean Annual Sequence in the Appearance of Water and Power." Paragraph "G" in this chapter is on "Necessary storage for the annual regulation as a means of measuring the non-uniformity of water in the course of a year." This sub-title

indicates the trend of the chapter; the author endeavours to use the duration curves, the summation curves and the "synthetic" chronological diagrams of river discharge and power production to establish a "criterion for economic value of a river."

A similar attempt is made in the last chapter when studying the "water fluctuation from year to year." This analysis establishes the general trend of the thesis of Mr. Yevdjevic.

Some additional remarks may well be inserted here.

It is generally accepted by most authors that the demand for electric power is doubling every 10 years. The trend is universal, it involves nations with very different levels of economic standard and the rule appears to have a character of generality. There are exceptions, but rather on the side of greater impulse in the demand for more power. Figures of 8-10% of yearly increase for whole nations, or of 10-15% for large provinces have been published.

Such rapid expansion of the electric industry involves possible basic changes (structural changes) in the expanding systems and—in some regions—the rapid exhaustion of the still available hydro-power resources. This may happen in 12-15 years in the European Alps.

New sources of electrical energy (nuclear) will have to be considered and a new, more profound division established between base load and peak-load energy. Typical of present-day unrealistic conditions are some countries where the average load factor of the hydro-electric energy is already substantially superior to the system load factor, with no alternative for peak-load power at acceptable prices. If electric systems are considered—not in their present-day static state—but as rapidly expanding systems, the trend should be reversed. Hydro-power reserves should be analysed from the point of view of possible peak-load generation in the future. This may imply changes in the conventional designs; new design criteria will have to be evolved, new types of hydro-power development may have to be considered. As a start, the analysis of the still available power resources should be carried a step further. When estimating these reserves, the correlation between the power availability and the demand curve for new power should be scrutinised. The ideas set out by the author in chapters 7 and 8 should be expanded.

A more general theory of the power demand in "expanding" systems considering the co-ordination of all types of power sources and their adjustment to the future demand is certainly wanted at this stage.

Hydraulic Energy Dissipators. By E. A. Elevatorski. Published by McGraw-Hill Book Company Inc., New York, Toronto, London. 9¼ in. × 6 in. × ½ in. 214 pp., including index. Illus. 1959. Price 77s. 6d.

This book is one of a series of engineering monographs published by the McGraw-Hill Book Company and adjudged by the American Society of Civil Engineers and a number of other American Institutions to be of unimpeachable technical quality and usefulness. It gives an excellent presentation of the theoretical factors involved and then deals with the practical aspects from actual examples derived from American practice. Mr. Elevatorski, who is head of the Hydraulics Department and Assistant Professor of Civil Engineering at the University of Arizona, considers virtually all types of energy dissipators used in conjunction with dams and gives design procedures for such components as hydraulic-jump stilling basins, valves and gates, bucket-type dissipators and drop-structure stilling basins.

Outlet control mechanisms are adequately discussed and there is an interesting chapter on model tests and hydraulic similitude—a matter of growing importance these days. Some interesting examples of erosion are cited and illustrated, the damage in certain instances being extremely severe and pointing to the necessity of taking every care in the design and construction of the energy dissipating means used.

Technical Dictionary on Dams. Published by the International Commission on Large Dams of the World Power Conference, in collaboration with U.N.E.S.C.O. Distributed in Great Britain by Percy Lund, Humphries & Co. Ltd., 12 Bedford Square, London, W.C.1. Second edition. 380 pp. Price 70s.

This enlarged and revised second edition of the Technical Dictionary on Dams will be welcomed by engineers everywhere. In fact, the need for an authoritative multi-lingual dictionary of terms used in hydro-electric engineering has increased to the point where it is almost as important an item of equipment as a slide-rule. It contains sections in French, English, German, Spanish, Italian and Portuguese, with a complex index system allowing cross reference from any one of the six languages to each of the other five.

Most dictionaries can be criticised in one way or another; this one attempts to cover too wide a field and, by including such prosaic terms as plain, delta, earth, temperature etc., it occasionally tends to exceed its terms of reference; for instance, the connection between a dam, marine climate, a cyclone and overhead expenses is a little obscure. If a technical dictionary is to be of maximum use to technicians, material commonly found in standard reference books could well be excluded.

However, the vast amount of research devoted to the preparation of this book will benefit everyone who has tussled with the unfamiliar written word; well produced, in an unusual but convenient format, the dictionary will be hard to surpass as a tool for the busy engineer.

Usines Hydrauliques (Hydraulic Power Stations). By Henri Varlet. Published by Editions Eyrolles, 61 Boulevard Saint-Germain, Paris (5e). "Aménagement Utilisation et Prix de Revient des Usines Hydrauliques." 1958. 212 pp., 104 ff., cloth bound, 3,100 fr. "Usines de Dérivation," Vols. I and II. Vol. I—Captage des eaux, canalisations a écoulement libre. 344 pp., 207 ff. 1958. Cloth bound, 4,600 fr. Vol. II—Conduites forcées, tunnels d'amenée en charge, usines souterraines. 1959. 276 pp., four plates, 136 ff., cloth bound, 4,400 fr.

At the end of the war and immediately afterwards, one comprehensive Spanish treatise in two volumes and at least two major American treatises on hydro power were published. Several excellent books in Italian then followed. More recently, several new textbooks came on the market in rapid succession: the three volumes by Prof. H. Press (Berlin), now in its second edition, the massive publication by J. Guthrie Brown and contributors (Glasgow, 1958) and now a French treatise by H. Varlet. Three volumes are available and a fourth will follow soon.

It would be interesting to compare all these treatises.

The Spanish and German publications have definitely an international flavour; examples are given from all parts of the world, the German textbook being the best collection of the latest design methods, the three volumes bringing a considerable amount of excellent drawings, plans and diagrams. The British effort also gives information from all over the world but is more concerned with describing the more conventional practice in hydro-electric designs.

The French treatise by Varlet is French from the first page to the last; the examples it gives, the approach to technical problems, the general treatment and the sources of information and biography, are all typically French. But none of these books is a copy or duplicate of any other. So vast is the subject that six textbooks in two or three volumes and over a thousand pages can be written, and read with interest, without exhausting the subject.

The first volume of Varlet deals in the two first chapters with very general design problems, mainly on estimate of power, arrangement of power stations, comprehensive river developments, with a short paragraph on turbines and generators. The usual chapter on hydrology is missing. Chapter III is the one which will retain the attention of most readers; it is on power and energy production, simultaneous running of storage power schemes, run-of-river stations and steam power, and finally on costs. The whole chapter is a systematic analysis of the method of running simultaneously several hydro-power stations, illustrated with examples from the French system, where storage stations in the Alps, in the Massif Central, in the Pyrenees and run-of-river stations along the Rhine and Rhône produce about half of the energy absorbed by the French grid. Concerning the costs, figures on French thermal power and on hydro power are given on page 181. French thermal power costs compare with British figures, but for hydro power, French figures seem to be on the high side. This may be due to the progressive inflation of the French economy during the period covered by the author's inquiry and also to the fact that storage schemes in the Alps, if located in France, Switzerland or Italy, are unusually costly compared with the cost of power storage in Canada or the United States. On page 186, the yearly financial costs are given as 8-10% of the capital costs and an additional 2-3% are given for running costs. The author then finishes the chapter by giving methods and data for estimating the costs of financing the development during the construction period, for estimating the necessary sinking fund and in developing mathematical methods for comparing costs of power from different power stations. This chapter will be read with interest by all those who have worked through volume III of Guthrie Brown's treatise. In spite of all the information given to the reader the impression remains that a most vital subject has hardly been touched. On such an important chapter for any country's economy, only the Austrian treatise by Musil is known to the writer in addition to the two mentioned here. This is by far too little!

Volume I of the "Usines de dérivation" deals with intakes and free flow channels (341 pages), volume II is on pressure systems (274 pages); over 600 pages covering all possible problems from fish passes to water hammer, from the hydraulic jump and translatory waves (a subject usually neglected by textbooks, dealt with here at some length: equations of de Saint Venant, methods of H. Favre, etc.) to bending stresses in circular pipes partially filled with water.

The general impression is that the author attaches more importance to mathematical analysis of problems of flow or stresses than to problems of design and construction. This may just be a reason for recommending the treatise to readers who already possess other sources of information.

There is no index and only few bibliographical notes, nearly all referring to French publications.

Aménagements Hydroélectriques. By R. Ginocchio. Editions Eyrolles, 61, Boulevard Saint-Germain, Paris V. 482 pp. 172 ff. 10 plates. Price in France, 3,757 fr. including post and local tax; abroad, 3,665 fr. post free.

The author, who is Chief of the French National Hydraulics Laboratory and has been an engineer in the Department of Roads and Bridges, designed this book in the first place for his students in the School of Public Works. The appeal of the book will therefore be primarily to the student and the young engineer wishing to obtain a grounding in hydro-electric practice; it is not intended for the specialist in any particular branch of the subject.

For the purpose in view, the book is admirably conceived. To embrace such an enormous subject as hydro-electric practice in a single volume is always a thankless task, but the author has succeeded in obtaining a balanced coverage of all sides of the subject with which the student will be concerned. Each section commences with a concise explanation, followed by the essential theory, and is illustrated by examples from actual schemes, chiefly but not exclusively French.

The book is divided into four main sections, dealing respectively with general principles; dams and retaining works; intakes and supply works; and turbines, pumps and power stations. Two appendices discuss scale-model tests and the economic comparison between hydraulic and thermal power generation. A bibliography containing 220 references is an acceptable concluding feature.

Loans at Work. An illustrated brochure issued by the World Bank gives a brief account of the wide variety of development projects which have been, or are being, brought into existence as a result of loans made to increase production and to raise standards of living. Among the water-power plants involved reference is made to Kariba, the new Salto Grandé project in Brazil, the Anchicayá station in Colombia, the Damodar valley scheme in India, the Arimine scheme in Japan, and other schemes in the Philippines, Finland, Austria and Italy.

Steel Wire Ropes. The Tyne Wire Rope Manufacturing Co. Ltd. have issued an excellently produced handbook describing the extensive range of ropes they manufacture. The publication not only gives full particulars of wire ropes and their capabilities in themselves but also gives many valuable tips in regard to their installation and maintenance.

"Dominion Engineer." The No. 3, 1959, issue of this house journal of Dominion Engineering Co. Ltd. is particularly interesting to hydro-electric engineers, as it is devoted entirely to "Dominion Turbines Abroad." Some famous power stations are referred to, extending from South America to Russia and from India to New Zealand.

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One man can easily operate two Benchers simultaneously.

To secure the rig, bolt holes are drilled and anchor bolts and wedges placed in and driven tight. The bencher is placed on the heads of the anchor bolts and the feed is locked at the desired angle with chained wedges.
The operator can easily drill additional bolt holes while the rock drills already set up are running.

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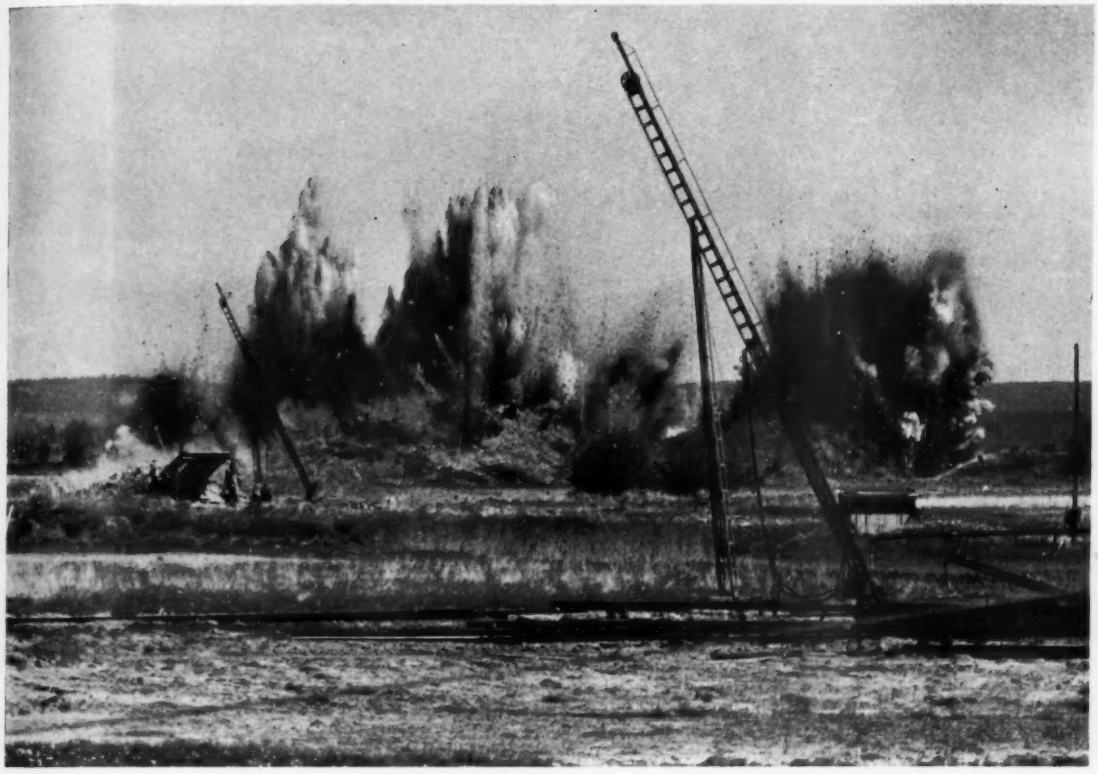


Fig. 1. Blast of 56 tons of dynamite to lift 90,000 cu. yd. of overburden

Blasting Water Channels

A new method is described of drilling and loading through the earth cover that has been successfully used on a canal project in Sweden

By STEN BRÄNNFORS, A.S.C.E.,
Skånska Cementgjuteriet, Stockholm

A NEW method of drilling and blasting rock without removing the overlying soil layers, has been developed in Sweden by AB Skånska Cementgjuteriet, and is being employed on a canal project. The first series of blasts culminated recently when one of 4,750 holes was fired with success.

The canal is being constructed to cut off a sharp bend in the Motala river between Bråviken fiord and the port of Norrköping, about 90 miles southwest of Stockholm. The section now being excavated is about 2 miles long (the whole length is 4 miles), and the finished canal will have a depth of 31 ft. and a width at the bottom of 180 ft.

The soilcap consists mainly of glacial drift lying on the bedrock, covered by a top layer of clay. Varying quantities of rock have to be blasted at about a dozen points along the length of the canal. Owing to the instability of the waterlogged clay, it was decided to drill and fire the blasts without removing the earth cover, and perform the excavation work as a dredging operation.

For the drilling work, special rigs were built with a 52 ft. feed. The drill is an Atlas Copco BBC 43 machine with a special device substituted for the regular rotation mechanism, giving considerably greater torque. This device rotates both a drill pipe and a 1¼ in. drill steel running through the pipe. The hammer blows are likewise transmitted both to the pipe and to the drill steel. The pipe and drill steel are sunk simultaneously through the soilcap, to the accompaniment of powerful flushing. When the pipe has been collared about 6 in. in the bedrock, it is uncoupled from the drilling action, and the hole is drilled to full depth in the usual manner by the drill steel alone. The steel is then withdrawn, leaving the pipe as a lining in the earth section of the hole.

To enable the hole to be charged after the drill pipe has been removed, plastic piping is pushed down

The only crawler-mounted loader with SWIVELLING ACTION

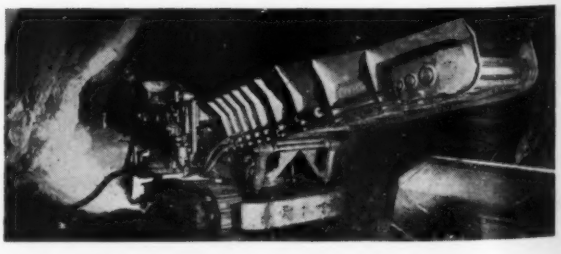
The new LM500 air-powered loader is the result of four years' development work under hard operating conditions. Designed for use in tunnels, mining drifts and general underground excavations where trackless transports are advantageous, the LM500 is the only crawler-mounted loader with swivelling action.

Output is high! The bucket capacity is 650 litres, the movement swift and *the throw can be made without centring*. The swivelling action allows a width of up to three metres (9′ 10″) to be cleared without turning the crawler bands.

A conveyor permits continuous discharge even when the loader is moving back and forth. Discharge height can be varied between 1,140 and 1,950 mm. (45·3″ and 76·8″) so that most types of dumpers can be used. Another advantage is that heavy boulders can be lowered gently into dumpers and transport cars. In fact discharge is so smooth that ordinary motor lorries can be used.

An efficient 28 h.p. traction motor and sturdy crawler tracks make the LM500 a powerful machine able to advance easily into any rock pile. Being air-powered the loader emits no diesel exhaust fumes—vitally important underground.

Maximum bucket height	**2,700 mm. (106·3″)**
Free discharge height	**1,150·6-1,950·7 mm. (45·3-76·8″)**
Free conveyor length	**2,530-2,700 mm. (99·6-106·3″)**



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L36

inside the drill pipe and made to plug in the collar of the hole by a simple external packing ring. The steel pipe is then pulled up.

Compressed-air Charging

The hole is charged by means of a compressed-air apparatus developed by the explosives manufacturers, Nitroglycerin AB. It consists of a plastic tube fitted with a breech opening that automatically closes when the compressed air is applied through a foot-operated valve. Except at the injection end, where there is a narrower mouthpiece to build up pressure and slit the cartridge wrapping, the loading tube has an internal diameter slightly larger than the 25-mm. diameter of the dynamite cartridges. Some 40 or 50 cartridges may be loaded at a time. Effective tamping action to give the required density of charge is obtained by an up-and-down movement of the loading tube in the borehole.

The priming charges, consisting of 22-mm. cartridges of blasting gelatine with two short-delay electric detonators, are placed near the bottom of the holes. After a few ordinary cartridges have been loaded and well tamped, the loading tube is withdrawn from the hole and a primer inserted in the mouthpiece. The tube is then pushed down into the hole with the detonator leg wires on the outside. The leg wires are provided with extra-strong insulation, and the blasting caps themselves are mechanically strengthened by means of a special outer shell.

Avoiding Propagation

Where the rock section is especially deep, primers are also placed in the middle of the borehole and near the collar. Thus for the recent 4,750-hole blast, more than 12,000 detonators were used to initiate 123,000 lb. of dynamite. The quantity of rock blasted was 36,000 cu. yd., together with 90,000 cu. yd. of overlying clay and moraine.

The large quantity of dynamite per cubic yard of rock is necessary in order to ensure an adequate degree of fragmentation for the subsequent dredging operation. The necessary concentration of explosive is achieved through considerably closer spacing of the holes than would normally be employed—about 1·5 meters instead of 2·3 meters. This in turn poses the problem of preventing any disturbance of the firing sequence by propagation. It was solved by first loading every other hole with 60% dynamite, and then going over the blast area again, using charges of 50% dynamite for the holes in between. In the wet holes, the sensitiveness of the 60% dynamite becomes somewhat reduced, although its explosive force remains unimpaired. And as the weaker explosive is in the hole for a shorter length of time, its water-resisting properties are quite adequate. Loading and hooking up the blast took altogether about six weeks.

Hooking Up the Blasting Caps

The number of intervals employed for the big blast was 31, with delays varying from 12-13 milliseconds between the first twenty numbers, to 25-100 milliseconds for the remainder. The holes were connected in 263 parallel series of about 45 holes each. Four twin-wire bus wires of bare copper which ran

Fig. 2. Inserting a dynamite cartridge in breech of a compressed-air loader

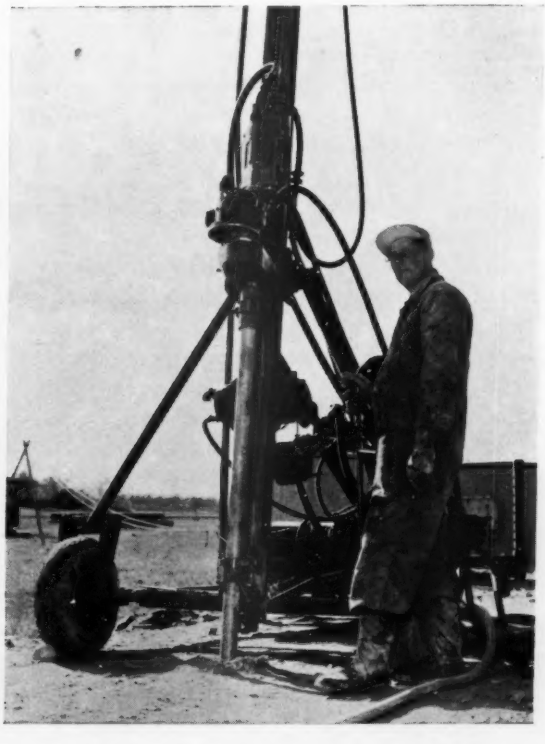
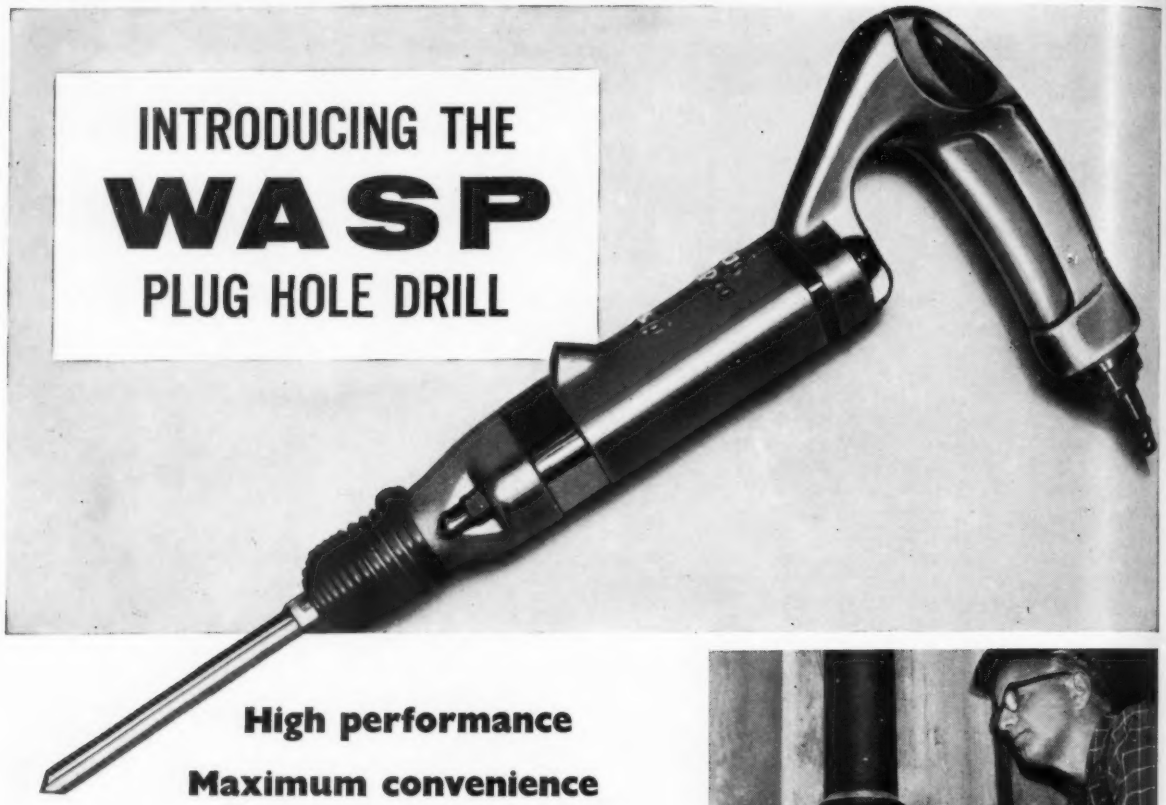


Fig. 3. A Lindö drill in wagon-mounted version showing drill pipe

INTRODUCING THE WASP PLUG HOLE DRILL



High performance

Maximum convenience

Ultra light weight

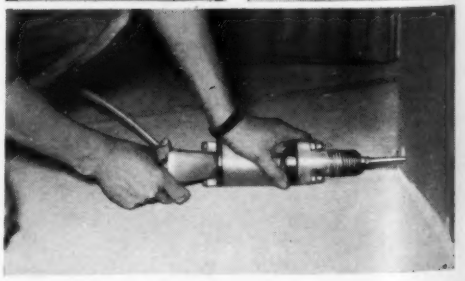
The Wasp is a new compressed air plug-hole drill designed for the building and stone working industries. It drills small holes from 10-19 mm. ($\frac{3}{8}$"-$\frac{3}{4}$") in stone, concrete, brick and other materials. The Wasp puts new power into the hands of carpenters, plumbers, electricians and fitters.

Weighing only 3 kilos (6.6 lb.), it is the lightest self-rotating pneumatic plug-hole drill in the world. Twin-controls enable the Wasp to be used with either hand—a decided advantage when working in restricted and awkward positions, both common problems in the building industry.

The Wasp works on the bob rotation principle used for rock drills (percussion and clockwise rotation), which gives it a high penetration speed. With air-flushing through the drill steel, the plug-hole is always kept clear. The drill has two-step throttle control: light pressure for starting speed, heavier pressure for full working speed.

The Wasp is suitable for use with Sandvik Coromant plug-hole drills with tungsten carbide inserts, and is supplied complete with accessories and spares in a strong transport case. It is the latest addition to the many pneumatic tools in the Atlas Copco range. Represented in ninety countries, Atlas Copco is the largest organisation in the world specialising solely in the design and manufacture of compressed air equipment.

Use it in any position



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P.34

the length of the blast area, hung on posts, were in turn parallel connected by cross leads. Connection with the blasting machine was by 500 leading wires with a cross-sectional area of 50 sq. mm.

A specially constructed blasting machine of the condenser-discharge type is used, power being supplied from a hand-driven generator. At 1,000 V the capacity of the machine is about 1,000 A and the maximum output is about 1,000 kW. In addition to the regular testing of the circuit and individual blasting caps for resistance, the leg wires of each cap are tested as soon as it has been inserted in the hole by means of a locally developed instrument for detecting the galvanic potentials arising from faulty insulation. The complete electrical circuit comprised about 300 miles of wire. The loading and firing procedure has been developed throughout in close collaboration with experts of the Nitroglycerin company.

Holes Through Boulder-filled Moraine

Previously some 120,000 cu. yd. of rock had been broken in smaller blasts, using 20,000 to 45,000 lb. of dynamite per blast. The blast described here was to break the remainder of the 157,000 cu. yd. section of rock at the entrance to the canal. Subsequent rock sections will all be smaller.

In sections where the average hole is 40 ft. deep (23 ft. of clay, 7 ft. of moraine, and 10 ft. of rock), the drilling rate has been 15 holes per shift. The annular cutting head of the drill pipe is fitted with carbide teeth, and the drill rod is tipped with a 2 in. detachable four-point bit with Coramant inserts. With the equipment employed on the Lindö canal projects, holes up to 65 ft. deep can be drilled through difficult moraine containing large boulders. With more powerful equipment the hole depth could obviously be increased. In addition to its use for blasting, the Lindö drilling method has been employed to drill anchorages for piles in sloping rock—the ability of the annular cutting head to collar a hole in such circumstances being thus used to advantage. The method has also been employed in connection with underpinning and other reinforcement work, on account of the possibilities it gives of drilling economically through gravel, boulders, timber, and other obstructions.

Other profitable fields of use include geological investigation. The equipment can, for instance, be employed to bore through the soilcap in order to determine the contour of the underlying rock formations; and with pipe of larger diameter, sampling equipment can be put down inside it to obtain soil samples. The method itself is patented.

Dredging Broken Rock

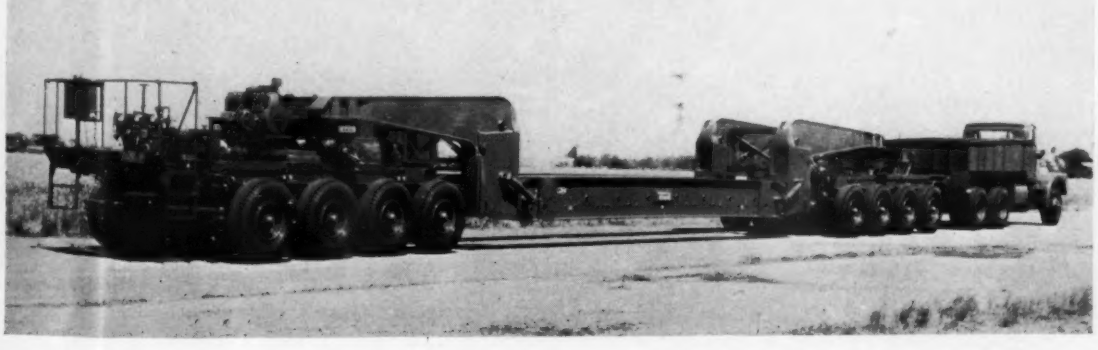
Dredging trials which have been carried out at Norrköping showed the fragmentation to be completely satisfactory. A new dredger which Skånska Cementgjuteriet has had built, with 0·8 cu. yd. buckets, has a capacity of about 600 cu. yd. per hour when dredging loose material. Blasting will take place successively along the canal as the dredger makes its way forward. In addition to the dredging in the canal, a channel extending about 2 miles out into the fiord will have to be deepened. In all, about 5·23 million cu. yd. including 26,000 cu. yd. of rock, will be dumped farther out in the fiord.

Compared with the canal's bottom width of 180 ft., the Kiel Canal and the Manchester Ship Canal are 145 ft. and 120 ft. wide at the bottom. Vessels up to 5,000 tons deadweight will be able to pass each other in the Lindö Canal, and with one-way traffic the depth of 31 ft. will enable tankers of up to 16,000 tons to steam full loaded right into Norrköping.

Crane Trailer for Spain

The accompanying illustration shows a Crane 100-ton low-bed trailer on its journey from Dereham, Norfolk, to La Coruna in Northern Spain, where it will be used for a hydro-electric project. The tractor and trailer were ordered by Fuerzas Electricas del Noroeste SA, which operates a number of power stations and distributes electrical power in Galicia, North-West Spain, and also feeds into the Spanish network. They were ordered mainly for the transportation of hydro-electric machinery from La Coruna to the site of the Company's next major hydro-station some 80 miles away at Belesar on the River Mino. The 410 ft. high dam will be situated across the gorge of the river, and the hydro-station will be entirely underground in the side of the gorge.

The route from La Coruna to Belesar lies mainly over mountain roads. However, such is the manoeuvrability of the 106 ft. trailer—it can turn in its own length—that no great problem has presented itself



A 100-ton Crane low-bed trailer

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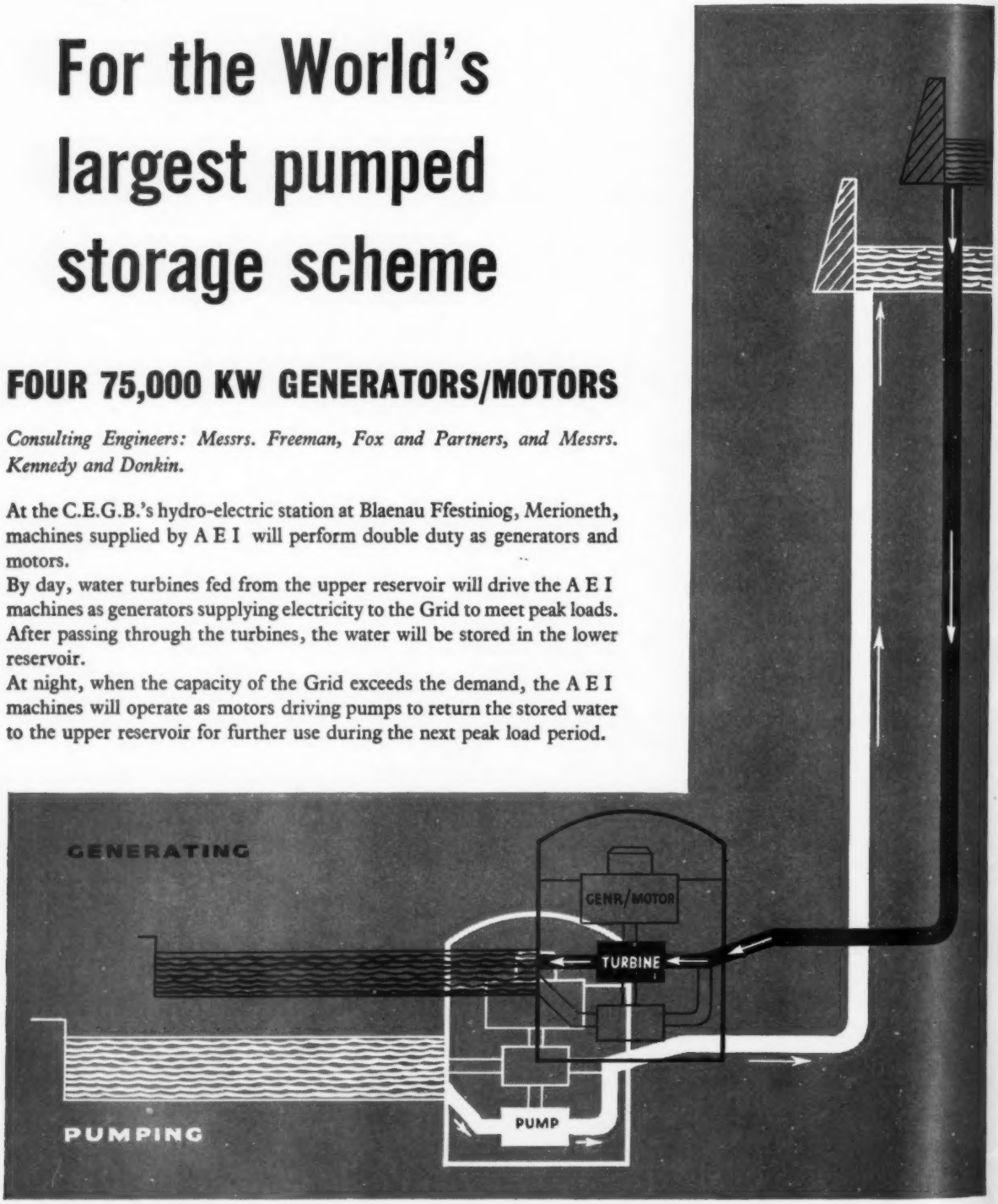
At the C.E.G.B.'s hydro-electric station at Blaenau Ffestiniog, Merioneth, machines supplied by A E I will perform double duty as generators and motors.

By day, water turbines fed from the upper reservoir will drive the A E I machines as generators supplying electricity to the Grid to meet peak loads. After passing through the turbines, the water will be stored in the lower reservoir.

At night, when the capacity of the Grid exceeds the demand, the A E I machines will operate as motors driving pumps to return the stored water to the upper reservoir for further use during the next peak load period.



ASSOCIATED ELECTRICAL INDUSTRIES LIMITED

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in the planning of the route to be taken.

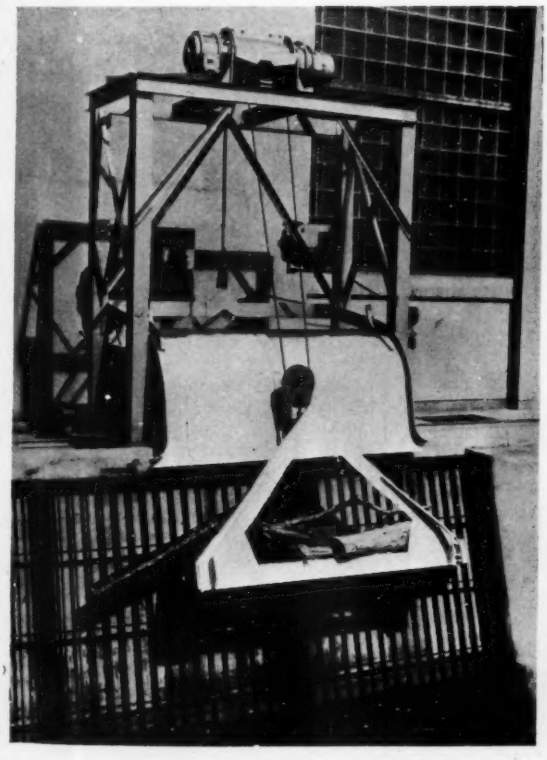
The trailer is hydraulically suspended, employing two identical bogies supporting a double-cranked frame fore and aft. Each bogie has 16 wheels arranged in pairs, on eight pivoting axles. Steering, which operates on all wheels, is automatic by means of mechanical linkage, or it can be controlled hydraulically. A generator set is incorporated to provide power for the various ancillary operations. The rear bogie is equipped with a cat-walk for the rear steersman, and a built-in loud speaker system is supplied for communication between him and the tractor driver.

The six-wheel drive tractor is powered by an 185 h.p. Rolls-Royce diesel engine, and the combination of gear box and transposing box gives 12 forward speeds and two reverse. Steering is power assisted. Air pressure braking operates on all wheels in the train from the application of the foot pedal, and alternatively from a lever on the steering column for use when restarting on a gradient. A ratchet-type hand brake applies the bogie wheel brakes independently.

The largest single load the trailer will carry will be the generator transformer supplied by British Thomson-Houston Export Company Ltd., and this will weigh in the region of 100 tons. Other massive loads will be the 88,000 kVA British Thomson-Houston generators, and the 104,800 h.p. Boving turbines.

Allis-Chalmers Trashrack Rake

A new trashrack rake, called the Leonard trashrake, is now available from Allis-Chalmers Manufacturing Company, Milwaukee.



Allis-Chalmers Leonard Trashrack rake

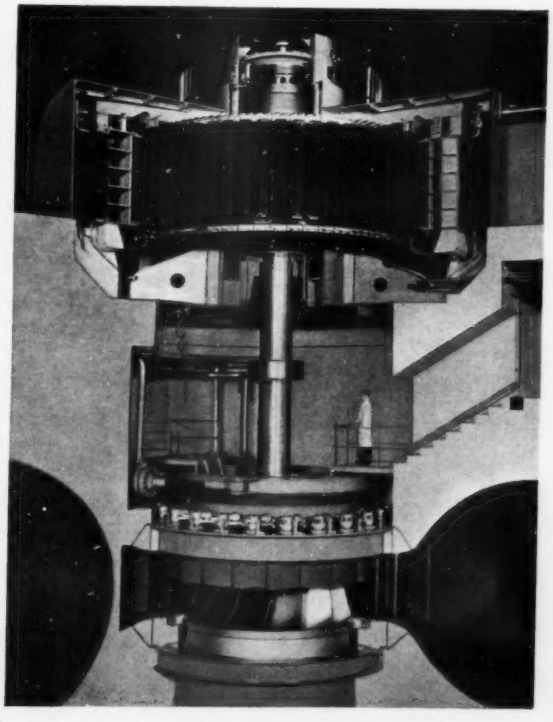
The rake is used on all kinds of stationary intake rack structures which have either inclined or vertical rack bars. One of its outstanding characteristics is its ability to ride down over stubborn obstructions and work them free. Easy cleaning of the bars is possible because no guides at the rack bars are needed.

An electric hoist raises and lowers the rake. When descending, the rake's teeth automatically turn upward parallel with the rack bars to clear debris. When ascending, the teeth tilt to a position perpendicular to the racks and penetrate between them to carry the debris to the unloading position. Removal of floating trash is speeded as the rake teeth rotate to the proper raking position without approaching either extreme of rake travel.

Initial cost of the raking equipment is kept low by having the trash rake operate directly on rack bars. It is not necessary to provide channel guides embedded in concrete piers at each side of the intake or attach the guides to the rack bars. Hence, the width of the rake can be kept at a nominal size and the expense of channel guides is eliminated.

German Contracts for Caroní

The Caroní-Macagua I power station being built on the lower cataracts of the Rio Caroní about 10 km. upstream of its confluence with the Orinoko, is about to be completed. This hydro-electric plant is one of the most important power stations in South America. The AEG is supplying the generators and J. M. Voith, G.m.b.H., Heidenheim, the turbines. When completely installed, six sets will be in operation, each having a rating of 70,000 kVA. The rated voltage will be 13·5 kV and the normal speed 116 revs. per min., the



Model of 70,000 kVA set for Caroní

Holman Group News

ANOTHER NEW HOLMAN PRODUCT

How much sludge will a Sludge Pump pump?

A real worker, the new Holman Portable Sludge Pump. It can handle very dirty, very contaminated, very gritty water, containing a high percentage of solids. And it uses very little air to do the job. This highly efficient pump is designed to work at low heads—but it can clear deep trenches, and sludgy deposits in coffer dams and caissons. No priming is needed; the action is entirely automatic, and the mechanism is self-sealing and self-cleaning, with high acid-resistance. Weighing only 78 lbs., it can be readily handled by one man.

Like all Holman products, this Portable Sludge Pump will amply demonstrate its capacity for continuous hard work, without breakdown, under the toughest conditions.

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runaway speed being 250 revs. per min., the set is of the umbrella type, W8, with a lower combined thrust and guide bearing with top-mounted exciters—main and pilot.

The power station is planned to supply the steel and rolling mills under construction in this territory. Cokable coal not being available in Venezuela, the steel plants depend entirely upon electrically generated heat. The provincial capital, Ciudad Bolivar, as well as the main districts of the iron-ore sections nearby will be supplied with electric current by the power station at the Caroní cataracts. The important ironworks at the Orinoko, melting high-grade ores on the spot, belong to this group. It is further planned to utilise the electric current as a supply of energy for the extensive development and colonisation regions in the State of Guayana, where vast unworked deposits of manganese, asbestos, aluminium and iron ore exist. The electrification plans of the Government of Venezuela also include the 200 km distant oil districts of Maturin, El Tigre and San Tomé, the most productive districts of Venezuela.

Abstracts from the World Technical Press

Plastics Lining in Steel Water Pipes

The possibilities of applying plastics as a lining or protective coating to steel water pipes are examined, and the results so far achieved are discussed. Coal-tar varnish and cement mortar have established a solid reputation as long-lasting protective coatings for such pipes, and they are still much cheaper than plastics in the moderate price range. Assuming plastics to be ten times higher in price than coal-tar varnish, industrial life and protective properties being equal, a plastics lining would have to be no more than one tenth as thick as a coal-tar lining to compete. So far, plastic coating and lining had been used mostly in conjunction with small-diameter water pipes; the only instance of plastic-lined penstocks mentioned is that of the experiments carried out at Shasta dam by the Bureau of Reclamation with phenyl and vinyl plastics. These penstocks have now been in service eight years and their lining is still in excellent condition. Other B.R. experiments on buried pipelines with vinyl and phenyl paint-type plastics have also proved satisfactory. From the various kinds of plastics discussed in this survey, vinyl plastics in rigid or flexible sheets appear to be particularly advantageous for large-diameter steel pipes. (Graydon E. Burett & Carl E. Selander, *La Technique de l'Eau*, Vol. XIII, No. 146, February 2, 1959, p. 35, 7 pp., 1 table.)

The Freibach Power Station

We have here to deal with a minor plant with an installed capacity of no more than 15,000 kW and sited on exceedingly rugged ground. It presents, however, on its civil-engineering side, some highly interesting features. The Freibach stream, a right-bank tributary of the Drau on its Austrian stretch (the Yugoslavs call it the Drava), drains a catchment of 44·4 sq. km., the discharge varying between 0·27 cu. m. per sec. in February 1933, and 61·00 cu. m. per sec. in November 1923. The installed discharge capacity of the plant is 5·75 cu. m. per sec. The earthfill dam, which creates a useful storage of 5·3 million cu. m. in a reservoir 39·4 hectares in area, is the first large-size structure of its kind in Austria. It has a volume of 235,000 cu. m., a height of 36 m., a width of 5 m. at crest and 185 m. maximum at base, and a crest length of 150 m. The central vertical core has a width of 4 m. at top and 14 m. at bottom, and a volume of 32,000 cu. m. Thanks to the presence in the immediate vicinity of the dam of adequate and accessible deposits of excellent fill material, the placing of the fill was easily organised. Work was started on May 10, 1958, and proceeded swiftly, and in spite of 24 days of bad weather was completed by the end of October 1958. The spillway consists of an overflow trough, U-shaped in plan, the tops of the U being abutted against the crest of the dam, and the trough connecting through the left-bank abutment with a steep concrete channel which conveys the water to the stilling pool. The spout of the channel was designed in accordance with the results of model tests carried out at the Graz Technical University, so as to ensure a maximum of energy dissipation. The power conduit between the intake tower and the penstock consists of six sections: two short initial tunnel stretches, 162 and 178 m. in length respectively, leading around the right-bank abutment of the dam and separated by the valve chamber, a 1,220 m. buried stretch of prestressed-concrete pipes followed by a 852 m. tunnel. There is a second stretch of prestressed concrete pipes 450 m. long, and finally a tunnel 1,141·5 m. long. With the exception of the 3 m. diameter initial sections, the tunnels are 2 m., and the pipelines 1·7 m. in diameter. A look at the longitudinal cross-section of the power system explains how it was possible to insert pipe sections between the tunnel stretches. The pipe sections are laid at two spots practically on the level in fairly shallow trenches. This solution proved 13% cheaper than steel pipes, and the aggregate length of the two pipelines, which are made of 5 m. sleeves, fully justified their manufacture on site. Downstream from the surge tank, the tunnel leads to the penstock, which consists of a horizontal section 316 m. long and 1·6 m. diameter, and a 667 m. steep section 1·5/1·2 m. in diameter connecting with the power house. The driving of the short tunnel section (173 m. long) of the bottom outlet between the valve chamber and the downstream end, proved the most difficult part of the whole construction work, owing to awkward geological conditions which cropped up unexpectedly after the first 50 m. of the section had been excavated. The power house, sited in the inundation plain of the Drau, is 20·4 m. in length, 10·9 m. in width and has crane tracks 8·5 m. above floor level. The solution adopted for the foundation construction consisted of making an open foundation pit, which was made possible by lowering the water table, this proving the cheapest and most favourable method since it was then possible to secure an impervious substructure. All the various parts of the works, as well as the mechanical and electric equipment, are described in detail. Work on the Freibach development began on July 1, 1957, and trial running started on December 22, 1958. (Contributed by KELAG,

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Kärnter Elektrizitäts-A.G., Klagenfurt, *ÖZE, Oesterreichische Zeitschrift für Elektrizitätswirtschaft*, Vol. 12, No. 4, April 1959, p. 229, 16 pp., 19 ff., 1 full-page colour plate).

Austrian Danube Development

This article in five instalments is mainly devoted to the Ybbs-Persenbeug power station (WATER POWER, June 1956, page 207). The second instalment (p. 1207–8) deals especially with the hydro-electric development of the Austrian stretch of the Danube, considered as a whole; when completed, its 15 stages will aggregate 2,078 MW in capacity and 13,632 million kWh in yearly production. These figures comprise, however, only half the capacity and production of the head and tail plants of the chain, Jochenstein and Wolfsthal, which stand respectively close to the German and Czechoslovak borders, half their output being supplied to the neighbouring country. (*Technica*, Vol. 7, No. 21 to 25, October 10 to December 5, 1958, p. 1165, 41 pp., 85 ff.)

Ice Problems

In this paper, read on January 22, 1959, at a meeting of the Linth-Limmat Association in Zurich, the author describes how ice affected the running of Aare and Rhine plants during one of the coldest months experienced in Switzerland. In February 1956 the average temperature was 9·3°C. below zero. After a short exposé of the theory of the formation of surface, frazil and anchor ice, the effect of this very cold weather on five older and three newer plants is described. Among the former, the Aare plant at Bannwil, fed by a diversion canal, appears to have been the worst affected. On Friday, February 10, the intake trashracks to all turbines were fully choked by frazil ice and power output sank to zero; attempts to keep open at least one turbine inlet failed, and it was not until the following Sunday that the headrace was again free from ice. At the two Aare plants at Wynau, power output sank to 6% on February 11; the right-bank plant connects with a spillway block while, on the left bank, the plant is fed by a 146 m. long headrace. Normal running could not be resumed until February 12 at 6 p.m. At the Beznau plant, powered by a diversion canal designed for a discharge of 411 cu. m. per sec., conditions were pretty grim, and ice in front of the trashrack reached a depth of 3 m. The newer plants instanced, Klingnau, Reckingen, Ryburg-Schwörstadt, stood the test much better and running was never completely interrupted. The various methods of ice prevention are reviewed, and the paper ends with a short account of the experience collected in Austria and U.S.A. in this respect. Dipl. Ing. K. Ackermann, *Wasser- und Energie Wirtschaft*, Vol. 51, No. 3, March 1959, p. 49, 10 pp., 15 ff.)

Analysing Arch Dams

This paper is an amplification of previous investigations reported in *Travaux*, December 1954, by Inspector-General Haegelen, of the French Department of Civil Engineering, and in the ASCE proceedings of May 1952 by W. A. Perkins. This study, which considerably widens the range of the results arrived at by these two authors, bears in the main on the following points: (a) Calculating the complementary hyperstatic stresses to be added at the crown to those obtained in the case of a perfectly rigid bond between the concrete of the dam, and the foundation and abutment rock, in order to make allowance for the deformation of the foundation ground; calculating, under the same conditions, the complementary radial deflection to be added to that obtained for the crown section in order to turn from the case of perfectly rigid supports to that of deformable supports. The development of these computations has been effected, as to the type of loads applied, without any other preconception than the assumption of a symmetrical distribution of the loads in relation to the crown. (b) Calculating the radial deflection from any point of the arch, the radial deflection of the crown section being known; these computations have been developed under the assumption of an evenly distributed radial load, and they are presented in such a way that they may be applied indifferently to cases of either perfectly rigid or elastic bond between dam and supporting rock. (c) Calculating the bending moment and the axial thrust at the crown, as well as the radial deflection of the crown section in the case of triangular loads symmetrically distributed on both sides of the apex, the base of the load triangle being at the supports and its apex at any point of the arch. These computations were effected under the assumption of a perfect bond between dam and supporting rock, while the influence of the deformability of the foundation ground can be assessed in the same way as stated sub (a). It is obvious that the study of the cases of rectangular (evenly distributed radial load) and triangular loads can easily be extended to cases of polygonal loads. (V. Bauzil, ingénieur en chef des Ponts & Chaussées, *Travaux*, Vol. 43, No. 291, January 1959, p. 1; No. 292, February 1959, p. 84; No. 297, July 1959, p. 423; 24 pp., 12 ff., 4 tables).

Future Developments in Water Turbines

The considerations set forth in this article proceed from the essential factors that come into play for any kind of machine: *1.* Weight reduction; *2.* Shorter periods of stoppages caused by overhauls; *3.* Maintaining optimum efficiency in operation. On these three criteria depend all the other requirements which must be taken into account in the rational design and manufacture of a turbine. When examining the possibilities of reducing weight the author emphasises the importance of small-scale model tests in order to ascertain accurately the limits within which a high-efficiency turbine can operate under fair conditions from the viewpoint of cavitation hazards as well as from the power aspect. A second possibility of weight reduction lies in a judicious selection of raw materials. Today, welded steel plates have almost completely superseded castings, except in the case of components which can be mass produced. In addition, attention is drawn to a series of technical points such as the new arrangement of the servomotor actuating mechanism, new arrangement of the mechanism controlling blade adjustment in Kaplan units, and, in Pelton turbines, the adoption of the multi-jet vertical-shaft type for large units. To reduce the time occupied by stoppages, every care must be taken to ensure an easy and quick dismantling of components subject to wear and tear, such as runners and guide vanes in reaction turbines, nozzles and their needles in Pelton units. It is not enough, however, to shorten periods of immobilisation of the plant; the necessity for frequent dismantling must be eliminated, and the goal aimed at is to build machines that can remain several years in

operation without any overhaul. In this respect, metallurgical research has provided manufacturers with new materials which lengthen the life of certain components particularly subjected to extreme wear and tear, and make overhauling less frequent. Coming now to maintaining optimum efficiency, efficiency has reached a value (up to 93%) which is difficult to better, but the effective value of this high degree of efficiency holds good only if the turbine is designed to maintain its mechanical condition. Chroming the parts of a component in contact with water has proved particularly useful in this respect, the French research work and tests now enable components weighing several tons to be hard chromed. The manufacture of runners has also greatly advanced in recent years. New alloys, such as aluminium bronze, give the runner blades much greater resistance to cavitation and erosion. Among recent improvements, the author mentions the introduction of compressed air into the turbines in which the runner is generally fixed below the downstream level of the tailwater, so as to check the power losses caused by the runner "paddling" in water. Mention is also made of the application of electronics to governing. (Ing. B. Bortolotti, *Bulletin Technique de la Suisse Romande*, Vol. 88, No. 6, March 14, 1959, p. 73, 10 pp., 17 ff.)

NOTE. This article is an adaptation of a paper printed in *Bulletin Technique Vevey No. 1*, June 1958.

Vltava Development: Orlík Stage

A short description is given of the 128,000 h.p. ten-blade Kaplan turbines, of which four are to be installed at Orlík, on the middle stretch of the Vltava river. These machines, fitted with adjustable blades and running at 187 r.p.m., are designed to pass a discharge of 150 cu. m. per sec. from a head varying between 44 and 70 m. One of the runners, 4,600 mm. in diameter, together with shaft and servomotor, was among the Czechoslovak exhibits at Brussels last year. (*Czechoslovak Heavy Industry*, No. 2/1959, p. 29.)

Technique and Economics of Ripping

The technical and economic advantages of mechanical ripping are emphasised as compared with drilling and blasting. Modern rippers are now equipped with three to five teeth which penetrate 15 to 30 in. according to tractor weight and horsepower, and the hydraulic ripping gear is mounted at the rear of the tractor, now generally track-mounted. Ripping techniques, which, of course, may vary from site to site, are briefly described. The economy achieved is illustrated by the example of a clayey-sandy, boulder-strewn, hard-frost area and considered "very tough going," in which a four-man crew of drillers required 5·4 shifts to loosen adequately 8,100 sq. ft., five ft. deep, in frost. A caterpillar ripper, working in an identical area, made four initial passes and one cross-ripping pass; the first layer was dozed off, and the process repeated to reach the 5 ft. depth. The ripper completed the 8,400 sq. ft. job in a mere 14 hours. The costs were as follows: drilling and blasting $728·15, mechanical ripping $328·23, which means a saving of $397·92 or more than 50%. Details are summarised in two tables. No mention is made of the ripping technique having being applied to work connected with hydro-electric schemes, but it is obvious that rippers could be used in many instances, such as loosening of aggregate deposits and dam foundation sites, and even, cross-section permitting, ripping of tunnel floors, etc. (R. D. Evans, *Indian Journal of Power and River Valley Development*, Vol. VIII, No. 11, November 1958, p. 35–37, 1 f.)

Collecting Channels for Spillways from Reservoirs

The study of the flow arising in a steeply inclined rectangular channel, fed solely by side spillways overflowing at constant discharge along the length of the spillway crest, has given rise to a recent experimental research. (Sassoli: *L'Energia Elettrica*, January 1959.) An essential characteristic of the flow examined is that the change from slow to shooting flow takes place within the fed portion of the channel. In this paper the author approaches the same problem from a purely theoretical angle and begins by considering the differential equation of an element of the flow, assuming the wall friction to be negligible, but taking taking into account the component of the weight parallel to the sloping bed, owing to the great slope of the collecting channel. He thus succeeds in drawing up the co-ordinates h_c (depth of flow) and s_c (distance from the beginning of the spillway crest), of the critical point where the slow flow becomes a shooting flow. If a denotes the discharge per unit length of the spillway crest, B the constant width of the channel, i the bed slope, and g the acceleration due to gravity, the values of the two co-ordinates result as follows:

$$h_c = \frac{4a^2}{i^2 B^2 g}; \quad s_c = \frac{8a^2}{i^3 B^2 g}$$

The author also discusses the tangents to the two integral curves (one of which refers to the surface profile of the case considered) crossing each other in that particular point. It follows that the slope of the two tangents depends solely upon the slope of the channel. In the final section of the paper, comparison with the previously established experimental results gives confirmation of the calculation. The small differences that occur may be imputed to the influence of the frictional resistances which, however, might easily be introduced in the same scheme of calculation. (Dr. Ing. Gianluigi Gusberti, *L'Energia Elettrica*, No. 5, May 1959, pp. 442 to 444.)

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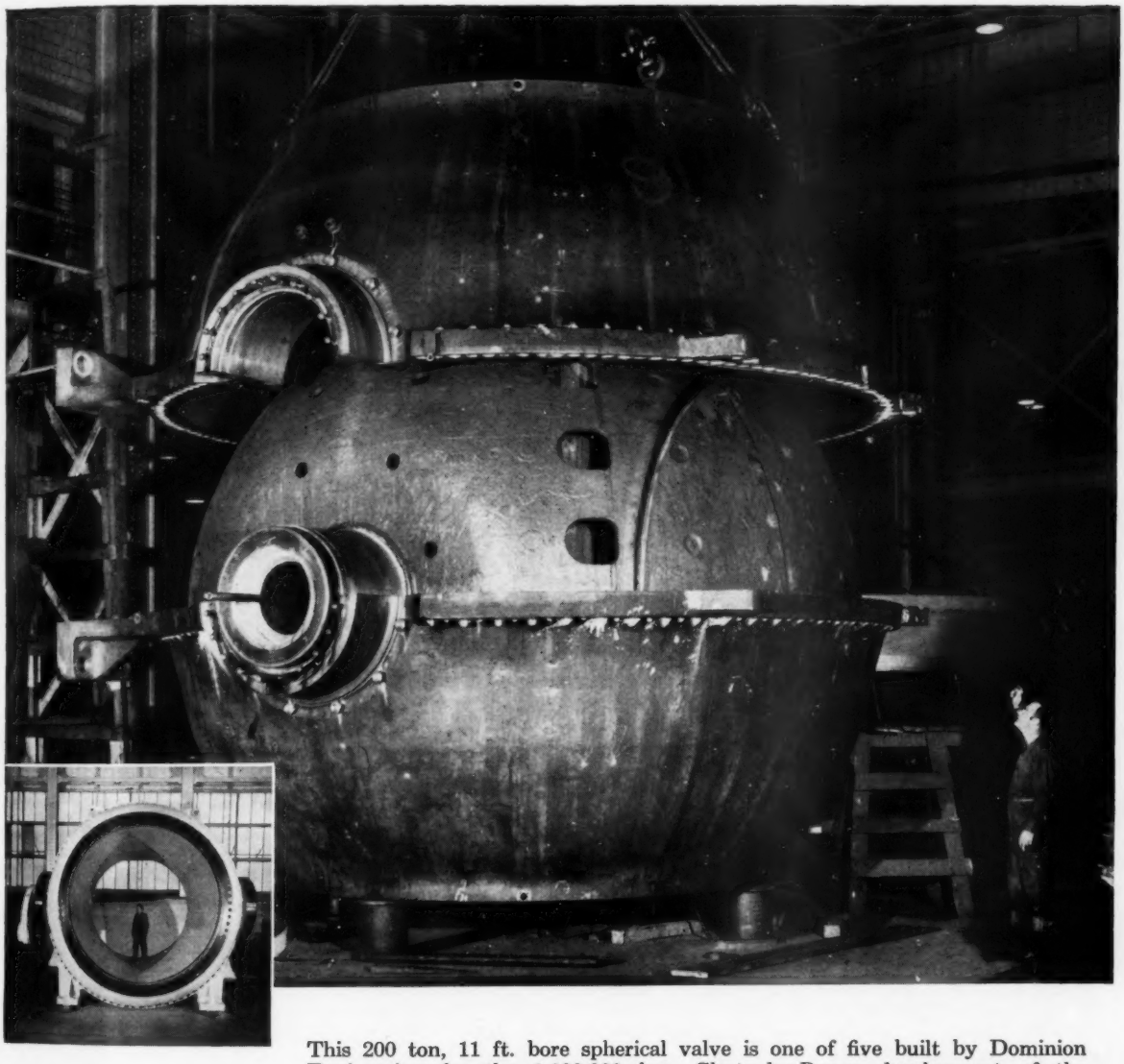

This 200 ton, 11 ft. bore spherical valve is one of five built by Dominion Engineering for the 1,000,000 h.p. Chute-des-Passes development of the Aluminum Company of Canada.

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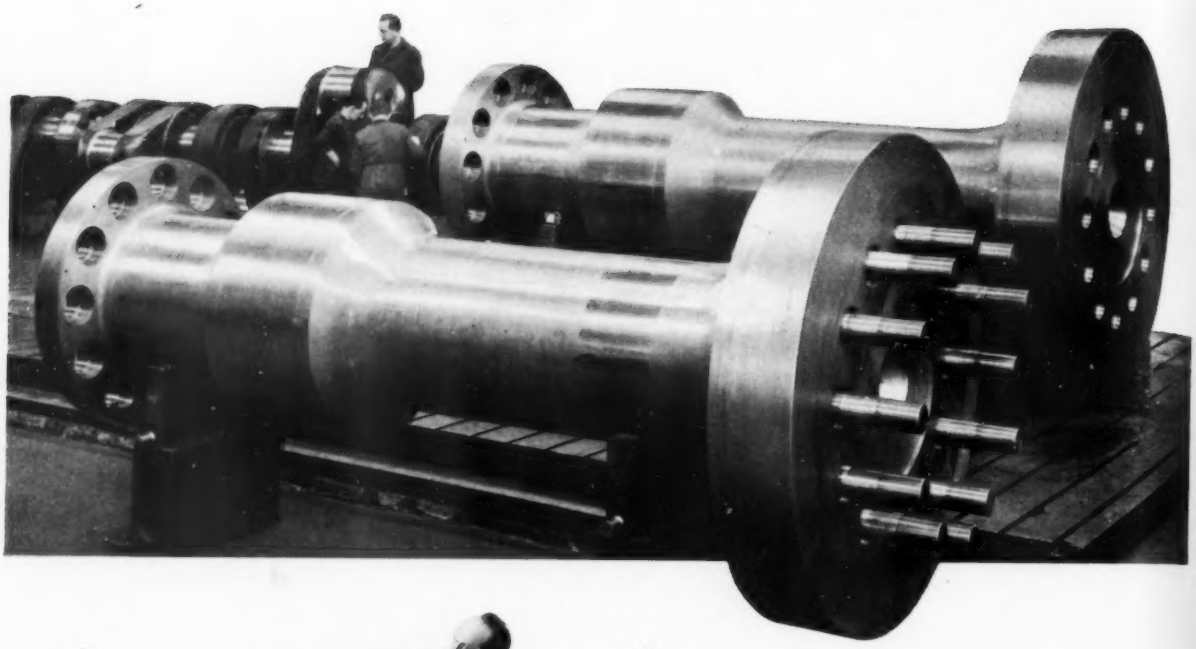

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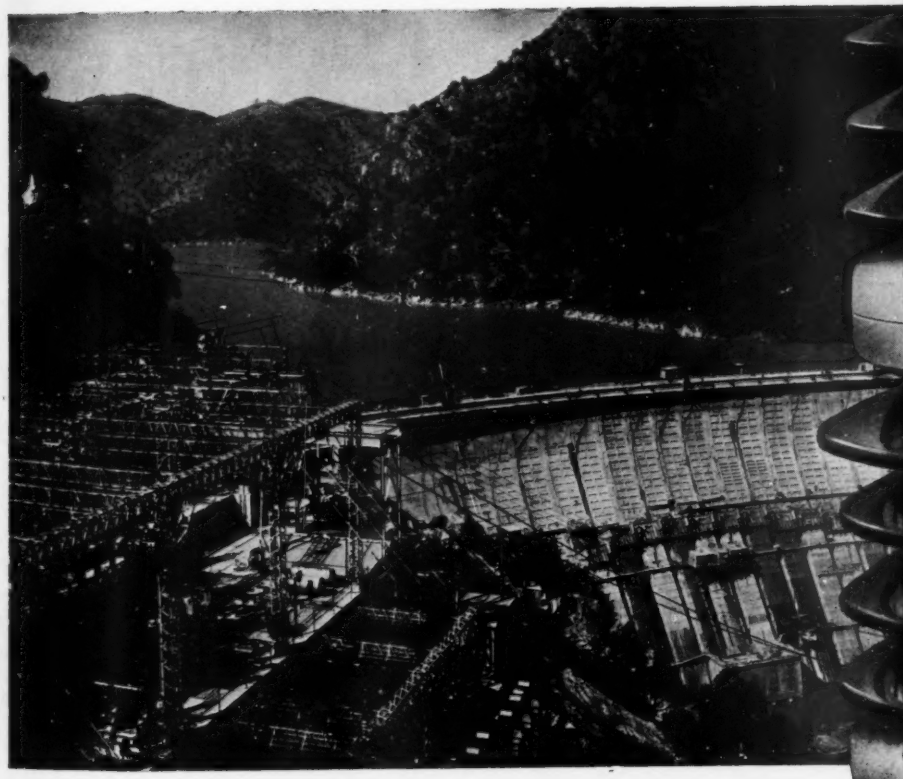

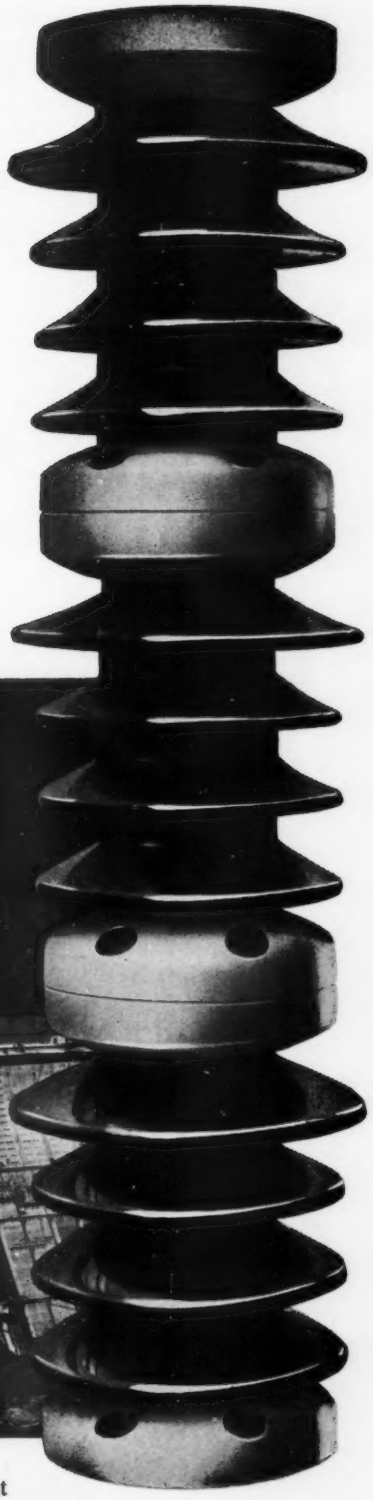

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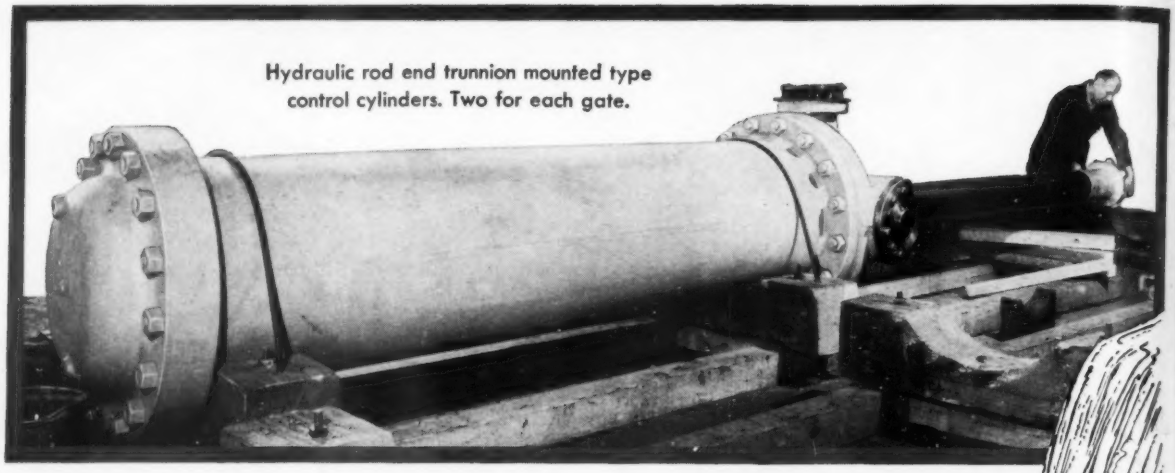

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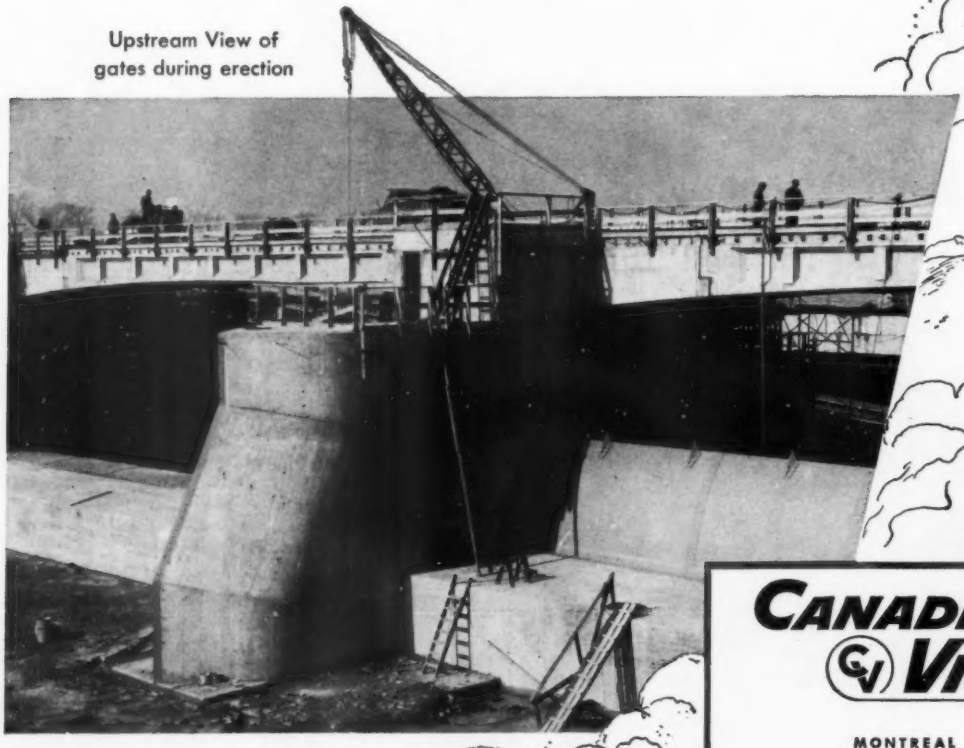

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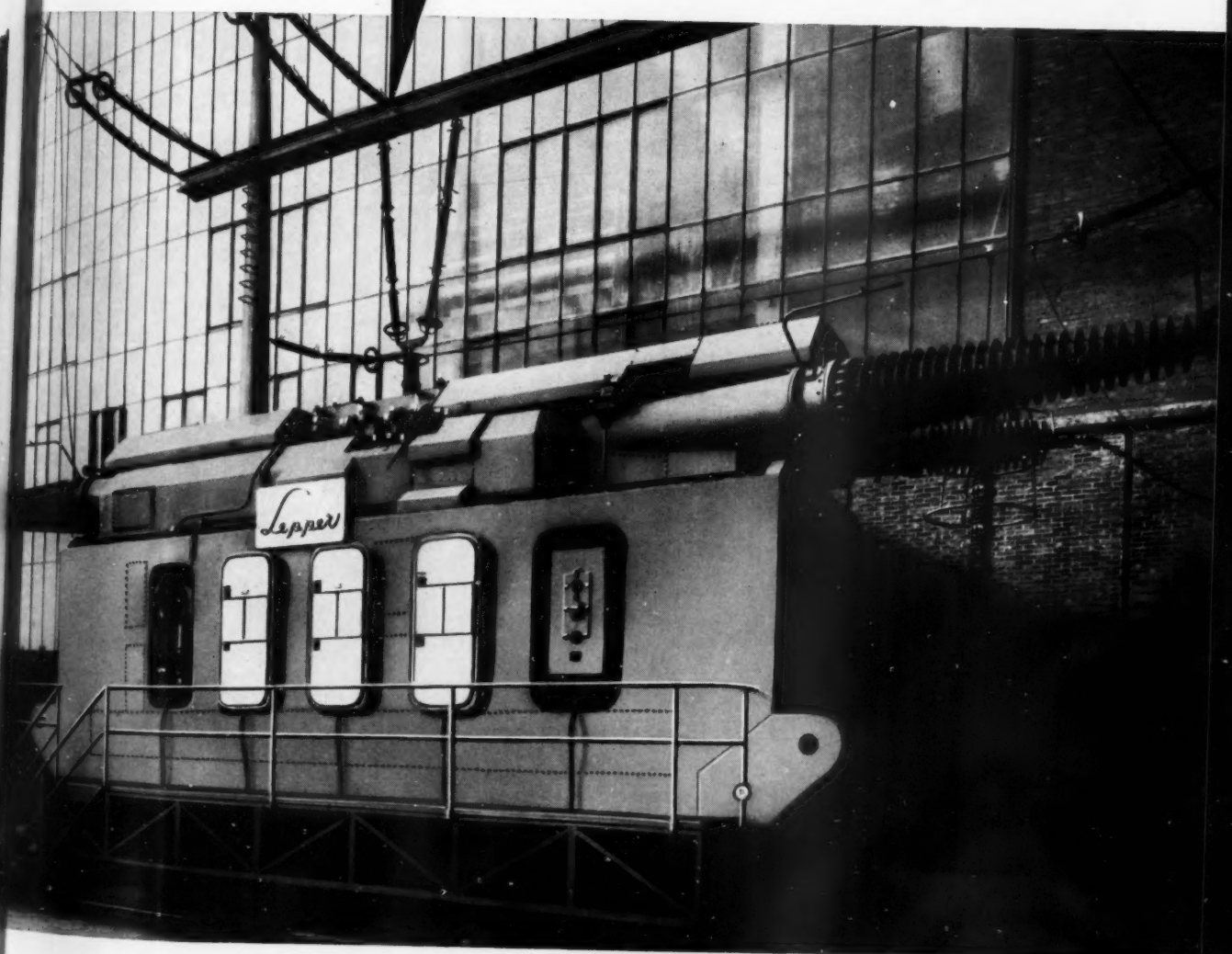

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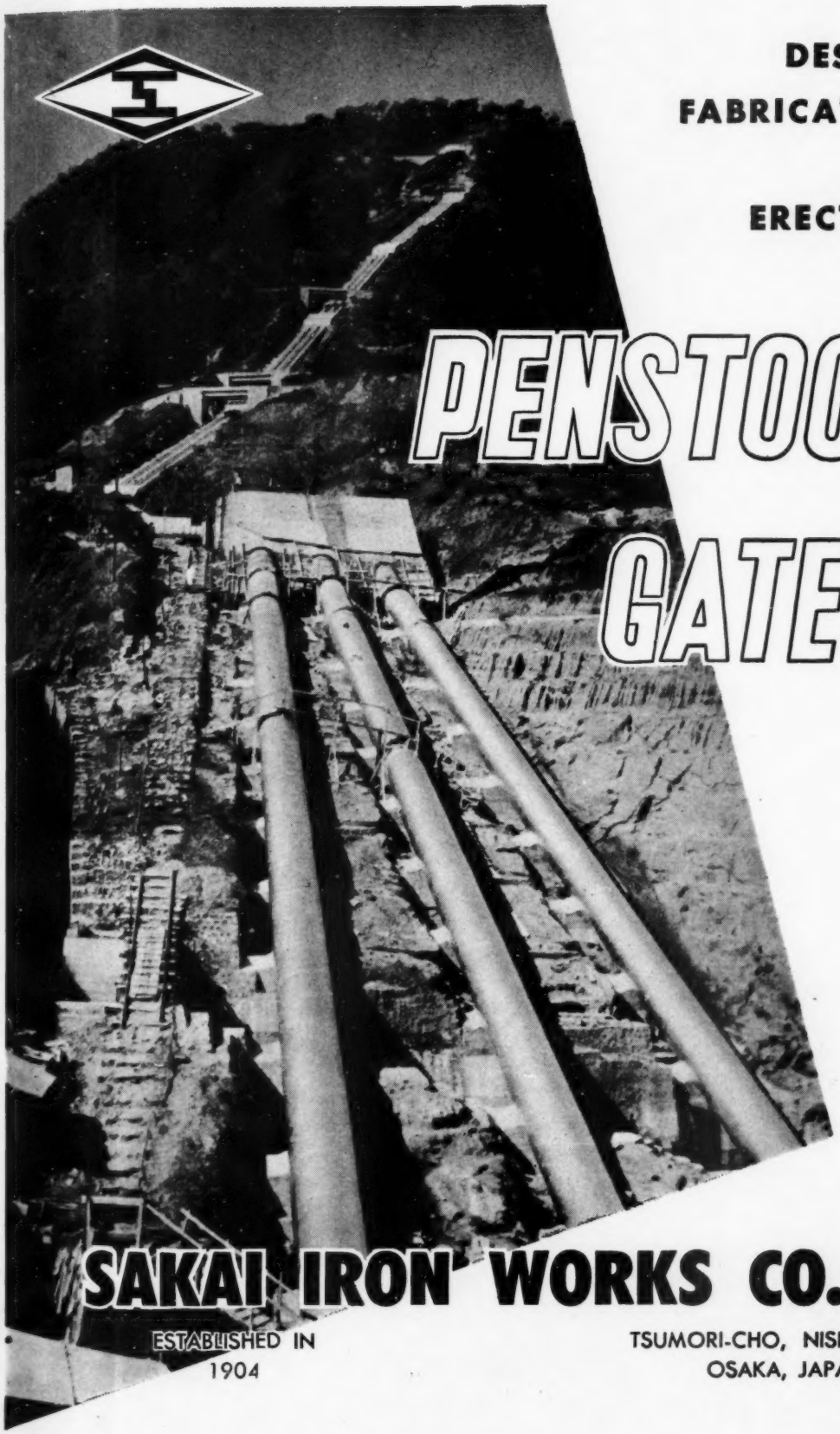

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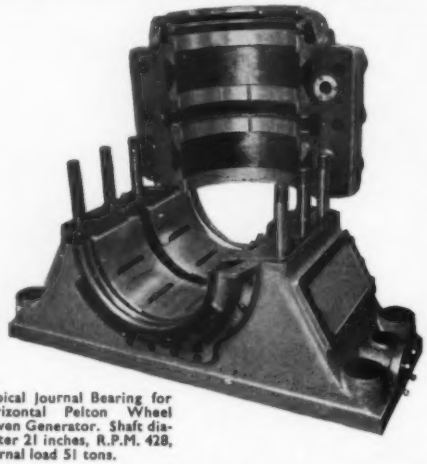

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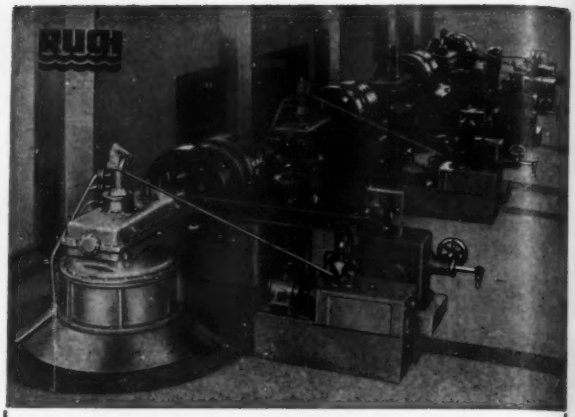

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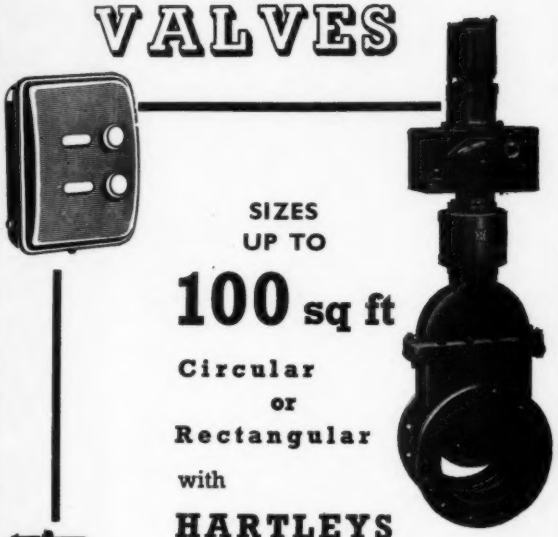

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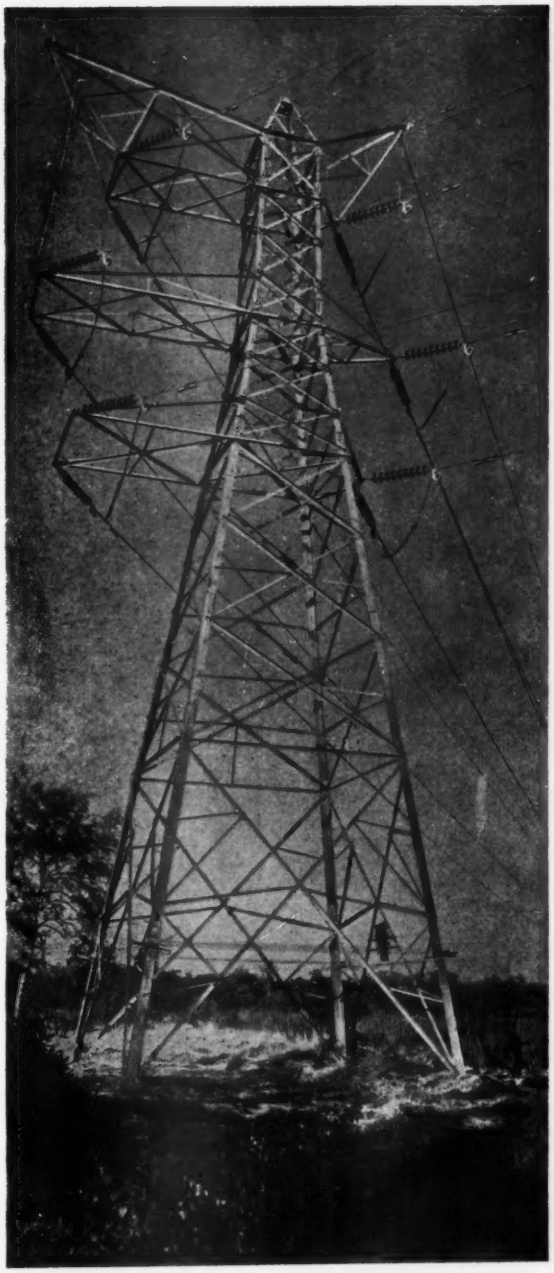

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INDEX TO ADVERTISEMENTS

A

A.C.E. Machinery Ltd. ... ... —
A.C. Plant & Hire Co. Ltd., The ... ... —
Acciaieria E Tubificio Di Brescia 50
Allen, W. G. & Sons (Tipton) Ltd. ... ... —
Allgemeine Elektricitäts-Gesellschaft 51
Allis-Chalmers Hydraulic Division 46
Allmanna Svenska Electriska Aktiebolaget 53
Aluminium Wire & Cable Co. Ltd. ... ... —
Anderson, Grice, The Company, Ltd. ... ... —
Ansaldo San Giorgio, S.p.A. 22
Armfield Hydraulic Engineering Co. Ltd. ... ... —
Associated Electrical Industries Ltd. 62, Outside Back Cover
Ateliers de Constructions Electriques de Della ... ... —
Atlas Copco, A.B. 59, 60, 61
Autair Ltd. ... ... —

B

Bell, Theodore & Co. Ltd. 7
Birkett, T. M., Billington & Newton Ltd. ... ... —
Bochumer Verein 19
Bouchayer & Vialett ... ... —
Boving & Co. Ltd. 5
British Insulated Callender's Cables Ltd. ... ... —
British Pitometer, The Co., Ltd. ... ... —
British Ropeway Engineering Co. Ltd. ... ... —
British Thomson-Houston Co. Ltd. ... ... —
Brown, Boveri & Co. Ltd. 10
Bruce, Peebles & Co. Ltd. 43
Bucyrus-Erie Co. Ltd. 30
Buss, A.G. 44
Butters Bros. & Co. Ltd. 21

C

Canadian General Electric Co. Ltd. ... ... —
Canadian Vickers Ltd. 68
Ceretti & Tanfani Ropeway Co. Ltd. ... ... —
Charmilles Engineering Works Ltd. ... ... —
Cockburns Ltd. 12
Commonwealth of Australia ... ... —
Compagnie Industrielle de Travaux ... ... —
Consclidated Pneumatic Tool Co. Ltd. ... ... 26 & 27
Craelius Co. Ltd. ... ... —
Crompton Parkinson (Export) Ltd. ... ... —

D

de Roll, Louis, Ironworks Ltd. ... ... —
Dominion Engineering Co. Ltd. 65
Doulton Industrial Porcelains Ltd. ... ... —
Drees & Co., G.m.b.H. ... ... —
Dresser Manufacturing Division ... ... —

E

Eimco (Gt. Britain) Ltd. ... ... —
ELIN, A. G. 16
Elliott Bros. (London) Ltd. ... ... —
English Electric Co. Ltd. 3
English Steel Forge and Engineering Corporation Ltd. —
Escher Wyss Ltd. 41

F

Ferguson Pailin Ltd. ... ... —
Ferranti Ltd. 18
Ferrum Montage 32
Fischer Ltd., George 64

G

Galileo Officine di Battaglia Terme ... ... —
General Electric Co. Ltd. ... ... Front Cover
Gilbert Gilkes & Gordon Ltd. ... ... —
Giovanola Freres, S. A. 38
Glenfield & Kennedy Ltd. 40

H

Harland Engineering Co. Ltd., The 56
Hartley's (Stoke-on-Trent) Ltd. 73
Helicopter Sales Ltd. ... ... —
Helicopter Services Ltd. ... ... —
Henderson, John M. & Co. Ltd. 34
Henley's W. T., Telegraph Works Co. Ltd. 8
Heywood & Co. Ltd. ... ... —
Hitachi Ltd. 23
Holland & Hannen and Cubitts Ltd. 58
Holman Bros. Ltd. 63
Horseley Bridge & Thos. Piggott Ltd. 14
Huhn, G. ... ... —

I

Impresa Farsura ... ... —
International Engineering Co., Inc. ... ... —
International General Electric Co. 47
Ingersoll-Rand Co., Inc. 55

J

Jonneret, S. A. Ateliers de Construction ... ... —
Joy-Sullivan Ltd. 42

K

Karlstads Mekaniska Werkstad, Akt. 9
Kvaerner Brug 28

L

Leffel, James & Company, The 48
Le Materiel Electrique, S-W ... ... —
Lepper Transformatorenwerk August 69

M

Magrini, S.p.A. 37
Mannesmann-Export, G.m.b.H. ... ... —
Marelli, Ercole & Co., S.p.A. ... ... —
Maschinenfabrik Augsburg-Nurnberg, A.G. 13
Maschinenfabrik Edward Ruch 72
Metropolitan-Vickers Electrical Co. Ltd. ... ... —
Micanite & Insulators Co. Ltd., The ... ... —
Michell Bearings Ltd. 72
Mitchell Construction Co., The 25
Mitsubishi Electric 24

N

Newport News Shipbuilding & Dry Dock Co. 36
Neyrpic ... ... Inside Back Cover
Nippon Gaishi Kaisha 54
Nuttall, E., Son & Co. (London) Ltd. ... ... —
Nydqvist & Holm, A/B ... ... —

O

Oerlikon Engineering Company ... ... —

P

Phoenix-Rheinrohr, A.G. 49
Pirelli-General Cable Works Ltd. 6

R

Ransomes & Rapier Ltd. ... ... —
Reyrolle, A. & Co. Ltd. ... ... Inside Front Cover
Rheinstahl Union Brückenbau-Akt. Ges. ... ... —
Rip Bits Ltd. ... ... —
Riva Costruzioni Meccaniche ... ... —
Rotork Engineering Co. Ltd. ... ... —
Ruhrstahl, A.G. 66
Ruston Bucyrus Ltd. 30

S

S. A. Ateliers De Secheron 31
SACE Costruzioni Elettromeccaniche 29
Sakai Iron Works Co. Ltd. 71
Salvi, A. & Co. 52
Salzgitter Maschinen Aktiengesellschaft ... ... —
Scarpa & Magnano 39
Siemens-Schuckertwerke, A.G. ... ... —
Smith, Fredk. & Co. ... ... —
Smith, S. Morgan Company ... ... —
Soc. p. Az. Cementi Armati Ing. Mantelli 35
Societa Elettro-Morsetterie Volpato ... ... —
Societa Nazionale Delle Officine Di Savigliano ... ... —
Societe Dauphinoise d'Etudes & de Montages ... ... —
Societe des Forges et Ateliers Du Creusot ... ... —
Standard Telephones & Cables Ltd. ... ... —
Steatite & Porcelain Products Ltd. 67
Storey, Thos. (Engineers) Ltd. ... ... —
Strachen & Henshaw Ltd. 17
Strommens Vaerksted A/S ... ... —
Sulzer Bros. (London) Ltd. ... ... —
Svenska Metallverken A/B ... ... —

T

Tampella OY 11
Technoexport 15
Tees Side Bridge & Engineering Works Ltd. 73
Tokyo Shibaura Electric Co. Ltd. ... ... —
Torno, Giuseppe & Co. 45
Tosi, Franco, S.p.A. ... ... —

V

Vereinigte Osterreichische Eisen-und Stahlwerke 4
Vevey Engineering Works Ltd. 20
Victor Products Ltd. ... ... —
Voith, J. M., G.m.b.H. 33
Voith, J. M. (St. Pölten) ... ... —

W

Waagner Biro ... ... —
White, R. & Sons (Engineers) Ltd. ... ... —
Wood, Hugh & Co. Ltd. ... ... —

Y

Yorkshire Electric Transformer Co. Ltd. ... ... —

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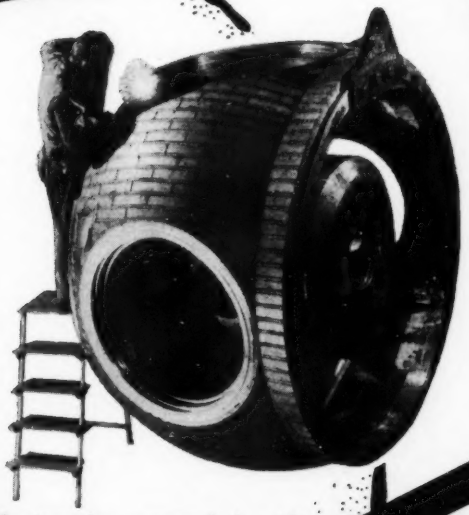
Saint-Malo

Brittany — FRANCE

Building-up the guide vane assembly



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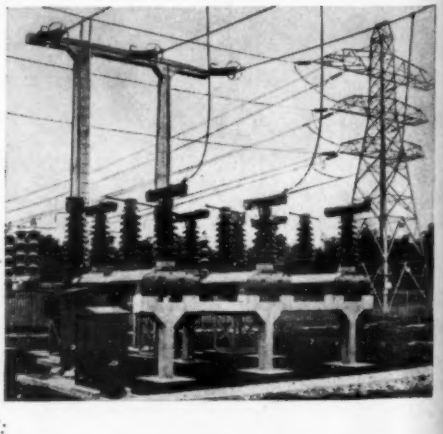

To reinforce power supplies in Buenos Aires, a ring of new 132 kV substations is being built around the city. These will be equipped with A.E.I. Air-Blast Switchgear having a breaking capacity of 5,000 MVA. The photograph shows a similar 132 kV type GA6W4 Air-Blast Circuit-Breaker installed in a British Grid substation.

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